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ABSTRACT

This document contains the papers presented at the Redesign in Science Education (RISE) Conference. Papers include: (1) "A Model Development Concept (MDC) for Education: A Framework for Change" (C. K. Barsky, K. G. Wilson, and B. Daviss); (2) "Teaching Science Everyday" (K. L. Scott); (3) "Science Teacher Licensure Requirements in Ohio" (P. Swami); (4) "What is Right and Wrong with Science Education?" (H. L. Gibson); (5) "Redesign in Undergraduate Chemistry Curricula" (C. W. Mathews); (6) "Informing Science Teacher Education Redesign in the USA with Knowledge of Practices in Germany and Japan" (T. Koballa and J. Riley); (7) "The New Turkish Science Teacher Preparation Program" (N. Yuruk and H. Seker); (8) "Reforming Science Teacher Education in Korea" (H. Kwon and G. Lee); (9) "Fostering Change in Science Education: The Israeli Experience" (U. Ganiel); (10) "Designing a Major for Prospective Middle School Math and Science Teachers" (A. Heckler); (11) "Redesigning a General Biology for Non-Science Majors" (C. A. Huether); (12) "The Education of Physics Graduate Assistants" (E. L. Jossem); (13) "Developing and Implementing a Critical Inquiry Approach to a Large, Existing Introductory Biology Program at a Research I University" (S. Rissing, M. E. Beeth, and N. Baker); (14) "Teaching High School Physics" (W. Heinmiller); (15) "The Role of Science Education Research Journal in Redesign" (C. Anderson); (16) "The Redesign of a Professional Organization to Support Redesign in Science Education" (J. Gess-Newsome); (17) "Redesign: The Changing Role of Professional Societies" (J. H. Stith); (18) "The BioQUEST Curriculum Consortium" (J. Jungck); (19) "System Reform at the State Level" (S. P. Meiring); and (20) "Science Pivots around the Middle" (M. Lightbody). (YDS)

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October 20-21, 2000

Westerville South High School

The Ohio State University

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SE064234

Redesign in Science Education

Edited by:

Michael E. Beeth

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(The Ohio State University)

The Redesign in Science Education (RISE) Conference was held by The Ohio State University October 20-21, 2000. It was supported by an interdisciplinary grant from The Ohio State University's Office of International Studies with matching funds from the College of Education, the School of Teaching and Learning, the Department of Physics Learning By Redesign Project, the College of Biological Sciences Introductory Biology Program, and the College of Mathematical and Physical Sciences.

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About the RISE Conference

Purpose:

The Redesign in Science Education Conference (October 20-21, 2000) provides an opportunity for all participants to share experiences and learn about principles upon which redesigned courses, curricula, programs, and system-wide efforts are taking place or might take place in the future. If you are a science teacher, administrator, university faculty member or a Graduate Teaching Associate at any level - middle school through university - and involved in or thinking about redesigning a course, curriculum, program or educational system, these proceedings from RISE should be of interest. Invited panelists at the RISE Conference include individuals who are just starting redesign efforts as well as those with multiple years of experience in redesign at various levels. Panelists will describe the lessons they learned from their redesign efforts and lead breakout sessions that involve conference participants in discussing principles for continuing efforts toward the goal of redesigning science learning. The primary goal of the RISE Conference is to develop sets of guiding principles that can inform future efforts to redesign courses, curricula, programs, and system-wide efforts whether these efforts are just beginning or currently underway. The secondary goal is for participants already engaged in a redesign effort to learn from other participants involved in similar efforts.

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RISE Conference Schedule:

Friday (October 20, 2000)

8:30 - 9:00	Registration and refreshments
9:00 - 9:30	Welcome and introduction
9:30 - 11:00	**Session I. What is right and wrong with science education?**
	Barsky, C. K., Wilson, K. G., & Daviss, B. (OSU)
	Scott, K. (St. Francis DeSales High School)
	Swami, P. (University of Cincinnati)
	Gibson, H. L. (Holyoke Public Schools)
	Mathews, C. W. (The Ohio State University)
11:00 - 11:15	Break
11:15 - 12:00	Breakout sessions by current project
12:00 - 1:00	Lunch
1:00 – 2:30	**Session II. Turkish, Korean and Israeli redesign in action, lessons learned along the way, assessment efforts**
	Koballa, T. & Riley, J. (University of Georgia)
	Yuruk, N. & Seker, H. (The Ohio State University)
	Kwon, H. & Lee, G. (The Ohio State University)
	Ganiel, U. (Weizmann Institute of Science-Israel)
2:30 - 2:45	Break
2:45 - 4:00	**Session III. US redesign in action, lessons learned along the way, assessment efforts**
	Heckler, A. (The Ohio State University)
	Huether, C. A. (University of Cincinnati)
	Jossem, E. L. (The Ohio State University)
	Rissing, S. (The Ohio State University)
	Heinmiller, B. (Westerville South High School)

Saturday (October 21, 2000)

9:00 - 10:30	**Session IV. Professional society and state level initiatives**
	Anderson, C. (JRST editor)
	Gess-Newsome, J. (President of AETS)
	Stith, J. (American Institute of Physics)
10:30 - 10:45	Break
10:45 - 12:00	**Session V. Defining redesign**
	Ganiel, U. (Weizmann Institute of Science-Israel)
	Jungck, J. (Beloit College)
	Meiring, S. P. (The Ohio State University)
12:00 - 1:00	Lunch
1:00 - 2:30	Breakout sessions by current interest
2:30 - 2:45	Break
2:45 - 4:00	**Session VI. Next steps**
	Wilson, K. (The Ohio State University)
	Lightbody, M. (Hilliard City School)

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Session I.

What is Right and Wrong with Science Education?

A Model Development Concept (MDC) for Education:

A Framework for Change

Constance K. Barsky, Kenneth G. Wilson, and B. Daviss.
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Abstract

The MDC for education is a framework for classifying education reform programs based on the characterization of processes. It supplements measurements of educational outcomes by functioning as a leading indicator of the likelihood of success of individual programs. The MDC relies on processes inherent in both knowledge accumulation and technological development: the development of expertise, the design of complex entities, the improvement of quality and the diffusion of innovations. Reading Recovery and Ohio's Statewide Systemic Initiative--Discovery are two examples of programs on the framework continuum.

Introduction

All students must acquire the intellectual and personal skills to enable them to thrive in today's competitive world. However, few institutions of education in the United States are close to attaining this goal (SCANS, 1991). Schools and institutions of higher education both are falling farther and farther behind in their attempts to meet the needs of today's students and the problems of inadequate education continue to mount. There is increasing pressure for reform to alleviate the continuing crisis (Stringfield, 1995). What should be done?

An Analogy

> Imagine a mountain climb organized the way education reform is now organized.

The path to the top starts out as a wide road, virtually flat, with frequent signs encouraging an unceasing flow of tourists. Typical signs along the path say "Mountain This Way: Anyone Can Succeed," "Join Us: No Experience Necessary," "A Pleasant Outing for the Entire Family" or "Follow the Crowd: This Many People Can't Be Wrong." A few miles in, the broad track ends in a vertical cliff rising thousands of feet into the sky, becoming steadily more difficult to climb as it rises. The tourists repeatedly struggle up the first few feet, only to fall off and try again. Eventually, disgruntled and bitter, most tourists stagger back to the trialhead by a narrower path.

A few of the most enterprising tourists succeed in making a little headway up the rock. The "best practices" that they had developed take them around the first few precipices, but soon they again encounter the sheer rock face and are left holding on for dear life. Occasionally, they fall, too. Some head back to the trailhead and others get up and try again.

Scattered across the face of the cliff are a few climbing expeditions, each the result of years of planning, fund-raising, equipment accumulation, and training. Before starting out, the expeditions stopped at the climbing hut at the base of the cliff. They studied the memorabilia of past climbs, the chronology of each new record height achieved, and the experiences of previous expeditions. While the summit remains unclimbed, the state-of-the-art advances enormously with each new expedition. Compared to the first climbing attempt three and a half centuries earlier, significant progress up the cliff has been made possible. Anyone who studies the records maintained in the climbing hut could verify this history, begin to understand the magnitude of the challenge, and accumulate information that will help to make the climb more manageable.

Some tourists who notice the climbers are disdainful of their relative success. Yet they castigate the climbers for not completing even so trivial a task as climbing the mountain. Meanwhile each tourist claims their own failure to reach the summit is someone else's fault--someone else blocked their way, fell down on top of them, or failed to provide adequate financial support; the excuses provided would be endless. The tourists heatedly deny that the cliff presents any difficulties serious enough to warrant the time and effort expended by the climbing parties.

Some of the more successful tourists--the ones a little way up the rock--constantly call attention to what they have accomplished, and constantly assure the

other tourists that success is possible for everyone. But these tourists, too, are resentful of the climbing parties. They assert that climbing expeditions are far too expensive, cannot possibly succeed, and cannot compete with what they themselves have accomplished.

A sheer cliff is an obvious example of an obstacle that requires a state-of-the-art to overcome. Mountaineers have been developing their state-of-the-art for centuries and there is an extensive lore of legendary climbers who achieved major climbing breakthroughs. Successful climbers, building on the experiences of their predecessors, launch expeditions characterized by careful planning, considerable funding, and, significantly, extensive training. In contrast, if nothing so difficult as a cliff is involved, anyone just walking along a trail can attain many mountain heights, although casual climbers often are lulled into attempting climbs that have dangers they do not recognize.

Most education reformers cannot conceive that reform is extremely difficult: a challenge comparable to a sheer cliff. They cling to the belief that reform (and education itself) requires no more than dedicated effort and adequate funding, more like an overnight hike through the woods by a large hiking party than a cliff climb. They have little understanding of the expedition-like efforts needed to lead reforms to predictable success in large numbers of schools. They have little or no knowledge of the reforms that are the most promising precursors for developing the school system required for the twenty-first century.

The few education reformers who have made a significant difference have achieved success in a number of schools. They recognized the challenges and surmounted them with long-term, carefully planned school "expeditions" which led them to their successes. For example, the programs cited by S. Stringfield (1995, p.71) as part of the Special Strategies Studies were selected because of evidence of promising results in more than a single school or district. Additionally, the body of literature from school effectiveness research may suggest other programs or program components essential to successful implementation of school reforms. What can we learn from these programs? Can we determine what it takes to mount a successful expedition up the sheer cliff of education reform? With all the confusion, conflict, lack of funding, and history of failures in education reform, are there criteria that can be used to predict the likelihood of success, especially during the early

implementation of a reform initiative?

We propose a supplement to the typical measurements of educational outcomes. Outcome measurements, such as standardized test scores, are *lagging* indicators. For example, statewide test score averages do not improve until more than half the population has been impacted. These results may take a considerable length of time to achieve because of the large number of students involved. Furthermore, any test score ratings shown on a curve do not provide the information needed to assess how many students fall below some absolute criteria for success. Such ratings are not tied to the goal of success for all students and are not used to identify causes of reform failure. By the time such outcomes could be observed and possibly used to provide feedback for program improvements, reforms may have been discontinued due to lack of funding, changes in school personnel, or lack of public support.

We propose, by contrast, a measurement of educational outcomes that utilizes criteria incorporating the characteristics of *processes*. *Processes* can serve as *leading* indicators, and as such can lead to more informed decision-making. Establishing the processes that should be a part of any reform, and monitoring the evolution of these processes, increases the likelihood of eventual improvement in outcomes such as standardized tests. The processes could enable reformers to assess progress and to focus attention on the needs most urgent for mid-course corrections.

We have identified some key processes from the analyses of two outstanding education initiatives, Reading Recovery (Clay, 1992) and Physics by Inquiry (Arons, 1990; McDermott, 1990), as well as from our experience with the National Science Foundation (NSF) Statewide Systemic Initiative in Ohio, Project Discovery, funded by NSF and the Ohio legislature (1991-1996). We propose a Model Development Concept (MDC) for education that provides a framework for classifying successive stages in an educational reform initiative. These stages begin with the initial concept and include various prototypes and scale-up stages. An initiative passes through these stages until it brings about major changes in a large number of schools.

The MDC framework incorporates the *processes* of research, development, implementation, evaluation and redesign--all commonplace stages in the technological world. It illustrates the continuum that exists between the inception of an innovative program and the recognition of that program as successful in improving education.

Model Development Concept (MDC) for education

The Model Development Concept (MDC) for education parallels the process of research, development, implementation, evaluation and redesign widely used in industry for product development. The initiation of a new product begins with small efforts that typically develop products with little applicability and of benefit to only a few people. In fact, Model 1.0, the first recognizable product, does not have to serve a market at all and might be used mainly to demonstrate that such a product is viable. For example, the main function of the first Apple computer or the Wright Brothers' first airplane flown at Kitty Hawk was to demonstrate that such a technology was possible. The step following is the introduction of the product to the marketplace. Once there is feedback that the product has potential, Model 2.0 development begins. For a technological product, Model 2.0 still represents an early stage of the technology. The Wright Brothers' first customer for their Model 2.0 airplane was the fledgling Signal Corps, representing a very small market. In contrast, today's aircraft are obviously far superior to Model 2.0 of the Wright Brothers. They fly many more people in far greater comfort at far less cost per person than was possible with the aircraft purchased by the Signal Corps.

The Model 2.0 product is the result of both comprehensive research and development-based redesign of Model 1.0. It is expected to be an improvement on Model 1.0 in three areas simultaneously: higher quality, broader applicability, and a lower cost-to-benefit ratio. Furthermore, Model 2.0 is expected to serve a growing market and have practical benefits. Each succeeding model builds on its predecessors through expanding research and development, and further implementation, evaluation, feedback and redesign. We claim that the same sequence is applicable to education programs.

The model succession is analogous to the succession of climbing expeditions necessary to conquer a difficult cliff. The challenge of bringing education reforms through a succession of models *before* one can expect their successful implementation in a large number of classrooms is a reflection of the cliff-like nature of education reforms.

We have identified five processes that should be integral to education reform programs. These are the *processes* of (1) acquiring basic knowledge, (2) building

technical cultures analogous to the hierarchy of expertise recognized by skilled mountaineers, (3) design, (4) continuous improvement, and (5) diffusion. The fifth process, the process of diffusion (Rogers and Shoemaker, 1971), is embedded in each of the other four processes, accounting for the degree of acceptance of programs signaling change. Although each of the processes can be discussed separately, the boundaries between them are not distinct. Each can contribute directly or indirectly to the others and there is no hierarchy.

We understand the process of the acquisition of basic knowledge in the context of Thomas Kuhn's *The Nature of Scientific Revolutions* (Kuhn, 1972). It is the process by which continuing research leads to the accumulation of scientific knowledge and to the development of logical theories. In education, basic research into how students learn and how to have them confront their misconceptions forms the basis of such programs as Reading Recovery (Clay, 1992), Physics by Inquiry (McDermott, 1990), and Cognitively Guided Instruction (Carpenter et al 1993). In Project Discovery (Project Discovery, 1995), our programs in life sciences and mathematics did not have as complete a background from research and development as did our program in physical science. Discovery's life science and mathematics programs demonstrated less consistency in the classroom and therefore were less developed on the Model continuum.

The next process, the building of a technical culture, or growth of professional development, is the process whereby there is a formal, recognized hierarchy of practitioners' expertise (Lortie, 1975). Furthermore, there are accepted procedures for transmitting this expertise to others. It is recognized that it takes time and practice to learn the technical culture. The Reading Recovery and Project Discovery models for professional development involve a minimum of 130 hours of contact between the teacher as student and the faculty as mentors. Contact hours include: observations of practice by both students and mentors, development of materials, and feedback on performance. A professional culture also recognizes that professional development does not take place in isolation. It values interactions among colleagues.

The third process is one of design. Designs are the product of conscious decision-making. Components in a design are selected because of what they can contribute to the overall effectiveness of the product. In order to link available resources (Hughes, 1990), the design of complex technological products requires

such processes as basic research knowledge and the expertise of growing design professions. Within the last decade, the introduction of Quality Function Deployment (QFD) to American industry has demonstrated the potential for focusing and guiding everyone involved in a project from design to delivery. QFD articulates and ranks perceived needs, details the technical requirements to fill those needs, and provides an organizational plan (Kinni, 1993).

The design of education reforms is no different. As in an industrial product, if choices are made simply to maximize the output of each component without examining the impact on the whole, a self-defeating process could result. For example, the structure of the professional development program in Reading Recovery was determined only after consideration of a variety of restraints on teachers' availability for professional development. Similarly, some of these same considerations prompted the evolution of new delivery methods in Project Discovery. Incorporation of design considerations forces the conscious selection of choices based upon the overall outcome desired rather than on maximizing each individual component.

The fourth process, Total Quality Improvement, involves procedures whereby one constantly examines the way things are done and looks for ways to improve the system or process. The Continuous Improvement, or the Total Quality in Education (TQE), movement adapted these procedures. This movement has become more visible within the last five years (Arcaro, 1995; Langford and Cleary, 1995). In 1999-2000, the Ohio Education Association, the Ohio Department of Education and the Ohio Board of Regents embraced the Baldridge criteria for quality in education. The TQE techniques, based upon those developed and implemented by W. Edwards Deming in industry (Deming, 1986), hold promise for significant advances in education outcomes, especially when combined with the other identified processes.

For fledgling education reforms to have maximum chances for success, the four processes should be in place, along with an understanding of the implications of the process of diffusion. The MDC criteria we propose demand that these processes become more visible and effective with each increasing model number, supporting transferable and sustainable programs that have broader applicability.

Examples of the MDC

There have always been schools and districts where exemplary teachers have had outstanding results. Exceptional teachers have transformed learning in their classrooms, visionary principals have led the way to wholly new directions in education. There are places where teachers collaborate and share practices, where students are no longer passive consumers, where learning is no longer governed by the clock and where students no longer have to fit into an existing organization with low expectations. There also are long standing professional organizations where teachers meet nationally to discuss their disciplines and share teaching tips. Over the past decade there has been a growing effort at the grassroots level to increase contacts among teachers formerly left out of these traditional opportunities for exchange. All of these activities deserve recognition for their successes in breaking the isolation of teachers and improving the education of their students. Unfortunately, these efforts have not impacted significant numbers of teachers or schools (Sarason, 1991).

There are sincere attempts to improve large numbers of schools by sharing the "best practices"--the most effective, efficient reforms now at work in individual classrooms. However, most reforms of highly experienced teachers are too complex to be adapted easily by other teachers (Sarason, 1972, 1996). To master this complexity, other teachers must have sustained periods of professional development, such as the year-long programs of Reading Recovery and Project Discovery. Moreover, most practices of individual teachers are very dependent on that particular teacher's unique skills, skills not likely to be duplicated by other teachers.

As a consequence, the novel "best practices" of experienced teachers deserve a Model 1.0 rating. They demonstrate new concepts or skills but lack the research and development needed for redesign, and the marketing needed to serve multiple schools.

In contrast to most reforms, "Reading Recovery offers US. education its first real demonstration of the power of a process combining research, development (including ongoing teacher education), marketing, and technical support in a orchestrated system of change." (Wilson and Daviss, 1994, p.76) Reading Recovery is an intervention program providing one-on-one tutoring for first graders at risk of failure in reading (Clay, 1985). Components of this program were consciously selected because of their demonstrated successful results over time in consistently reducing illiteracy. In New

Zealand, where the program originated, Reading Recovery is approaching its ultimate goal of having almost no students leaving the first grade without being able to read.

Reading Recovery in the United States today, as adapted and disseminated by the program at The Ohio State University, meets the three criteria for product improvement as compared to a Model 1.0 initial stage. It has higher quality in that most students tutored catch up with their class instead of remaining behind through second grade or even forever. Efforts to duplicate this success with teachers lacking Reading Recovery training have failed. Reading Recovery has broader applicability--more of the hard-to-reach students catch up with their class than in any conventional reform. It also has a lowered cost-to-benefit ratio compared to most grassroots efforts, provided the savings in special education costs and the savings in reduced retention in first grade are included in the benefits.

Reading Recovery's sustained professional development and its attendant cost savings were made possible by basic research. Furthermore, basic research results underlie the assessments of student outcomes. The research results help identify a long list of specific reading problems, instruct teachers in recognizing these problems, and provide demonstrated solutions. They ensure that Reading Recovery can be predicted in advance to be successful in a variety of schools and environments, including schools in other English-speaking nations.

However, a most stunning feature of the program is its design. Like any serious education program, Reading Recovery has numerous implementation details: job descriptions of Reading Recovery teachers, teacher leaders, and university-level teacher trainers; scheduling of year-long training for each position; specific professional skills expected in each position and a training plan ensuring these skills are learned; and the process for surviving the clock "resettings" when a new principal or superintendent is appointed. In addition, there is a feedback loop. Performance results for each child are submitted to the university training site so that the whole system improves with accumulating experience.

Every detail has been worked out to assure maximum success for students for minimal cost both in staff time and dollars--a design process not typically employed by educators. To give one example, Reading Recovery classroom teachers attend three-hour sessions once a week, at night, in their home district, throughout their training year. This format enables classroom teachers to work their normal hours in

school, as opposed to a more traditional but more costly format of a one-year program in residence at a university, a program that Reading Recovery uses for teacher-leaders and teacher trainers.

The most noteworthy achievement of Reading Recovery is how it has spread to over 6,000 schools and 12,000 teachers with no watering down of the strength of its support per teacher. The full year of strenuous training for its teachers is unchanged, and the ongoing support for a teacher-leader is unchanged. As the number of Reading Recovery teachers has increased, so has the number of teacher-leaders. Virtually all other programs of professional development have had to choose between remaining small and intensive or expanding while reducing the support per teacher.

Reading Recovery is near Model 2.0 on the MDC model continuum. It is not higher because it is still at an early stage of development. "It is neither ideal nor mature. It hasn't integrated with other reforms.... It hasn't been evaluated by independent analysts or compared in effectiveness to a range of other programs.... It also hasn't been progressively redesigned to incorporate insights from cognitive research or from teachers' growing experience." (Wilson and Daviss, 1994, p.76). However, Reading Recovery demonstrates the importance of processes in assuring successful educational outcomes--the same processes that are central to technological innovations. Reading Recovery leads the way for education reform by setting new standards for high quality, low net cost, and benefits for hard-to-reach children.

The experiences of Reading Recovery--the professional development concept, the year-long training, the teacher-leaders supporting classroom teachers, the use of proven research-based curricula--are transferable to other programs. These components, coupled with the cyclic redesign process, were adopted by Project Discovery. Project Discovery successfully translated the Reading Recovery model to teaching mathematics and science to middle school teachers. Proliferation of results in both these programs is impressive. Eleven Project Discovery university faculty, with a network of 52 teacher leaders, trained over 2,500 teachers who reached over 40,000 students per year. (Project Discovery, 1992-1995).

Professional development programs of both Reading Recovery and Discovery have resulted in significant improvements in student outcomes (Clay, 1992; Discovery, 1995; Kahle and Rogg, 1995). Even before the student outcomes could be observed, however, there were prior indicators that the programs were having an

impact. In both programs, there was early evidence that teachers' behavior in the classroom was transformed, that the reported and observed changes in behavior were sustained over time, and that the results were predictable in a wide variety of settings.

Our understanding of the development of Reading Recovery and its application to and further evolution of Project Discovery led us to propose the MDC for education. Examination of other programs such as Success for All (Slavin, et al, 1992) and cooperative learning (Johnson, Johnson, and Holubec, 1993; Kagan, 1995), collaborative learning (Bruffee, 1993) and complex instruction (Cohen, 1986) strategies suggest that some of the proposed processes can be identified in other educational programs. Typically these programs exhibit a dependency on basic research knowledge, redesign, and a technical culture (professional development).

However, we have not identified any educational program that has systematically incorporated the processes of continuous improvement and the processes for diffusion. Without these two processes, the model upgrade process is not complete. Implementation of the processes for continuous improvement provide templates for systematically examining quality compared to customer needs/wants. The processes for diffusion provide needed perspectives about the location of an innovation on the model development continuum and the likelihood of further adoption by the educational community.

The successful experiences with Reading Recovery and Project Discovery, as compared to other unsuccessful educational reforms (Fullan and Stiegelberger, 1991; Sarason, 1991) reinforce the MDC. The model leads us to expect that successful programs will: demonstrate evidence of a research basis for actions, result in transformations of teaching behavior in the classroom, and have a design-redesign capacity utilizing TQE techniques. In addition, these programs will demonstrate sustainability over time, transferability across disciplines and grade, and predictability in a variety of settings. Programs with these characteristics are more likely to succeed and positively impact student learning.

Reading Recovery and Project Discovery are part of a comprehensive process of change. They signal the emergence of an educational system established on both a growing base of research knowledge and widely disseminated exemplary practice instead of a system based on the endless recycling of old educational fads. The MDC framework identifies education reform programs most likely to succeed. The MDC

incorporates processes that work for educational innovations as well as for technological innovations in business and industry, and it should be applied to programs claiming to have answers to problems confronting education.

We invite you to join us in identifying programs that have begun to establish a foothold on the cliff of education reform.

Notes

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Teaching Science Everyday

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Introduction

Teaching science everyday involves a variety of goals to help students understand scientific concepts, integrate mathematical understanding and develop effective problem solving skills. The teacher must have an active role with the students in their learning process. The teacher needs to be well versed in facilitating classroom discourse, posing appropriate questions, and incorporating technology into the classroom. The task continues to grow, as the teacher has to effectively manage these goals with the daily school schedule.

For me, teaching science everyday is a reflection of what interactions are important to occur in my science classroom. I interact with students in the 9^{th} grade in Physical Science and in 12^{th} grade for two levels of Physics. My underlying goal is that students build their confidence in their science understanding and how to access their own learning. To disseminate my ideas, I would like to address goals I have for my students, my teaching goals, teaching science on a daily basis and professional development that has been the most effective for my development as a science teacher.

Student Goals

I have three main goals for my students. It is vital to me that students acquire a conceptual understanding of the science content. I want them to develop mathematical and graphical analysis skills to integrate the science with the math. Problem solving skills are also critical, as it often becomes a strong link between scientific reasoning, science concepts and the analysis of information.

First, and foremost, I feel students need to have an understanding of science concepts. I utilize ideas from conceptual change learning to accomplish this goal.

When introducing a new concept, I elicit individual student ideas before they are informed of the scientific perspective. Students become engaged in classroom discourse, sharing their ideas and listening to different points of view. Students begin to look critically at their own ideas, evaluate their ideas relative to others and analyze what and why certain conflicts exist. Once I introduce the scientists' 'perspective discussion continues as students openly compare perspectives and evaluate their current status of understanding. This process promotes students' active participation in the classroom, enhances their ability to think about their own thinking.

Another goal is that students acquire the ability to integrate the science concepts with the mathematical and graphical interpretation. I want my students to understand science from multiple perspectives-- to realize the link between science concepts and the expression in a mathematical, graphical or a pictorial form. I also want them to be able to apply their science understanding in different contexts.

Problem solving is the hallmark of students' understanding of the science. It is here they can incorporate their prior knowledge and new experiences to solve a given problem situation. In this process I want the student to become active in thinking about his or her own thinking process of how to solve the problem. I like to issue three questions before students engage in problem solving: What do you know about the problem? What do you need to know to solve the problem? How will you find out this information? I encourage students to use their skills and knowledge from other courses and experiences. Problem solving also involves students utilizing technology in the classroom to aid understanding. I incorporate various software and hardware to help students discover and support major science concepts from multiple perspectives. These skills help them make appropriate decisions about real-life situations.

Teaching Goals

I strive to actively engage my students in their learning process. For this to happen, I incorporate an active teaching environment, utilizing a variety of teaching and assessment techniques to facilitate their understanding of both the science and their learning process.

One of my teaching goals is to critically listen to students' ideas, understand why they have certain ideas, and develop effective questions and wait-time to

facilitate their responses. I use various techniques and questions to elicit students' ideas about certain science concepts and their own thinking processes. Questions are designed to cause students to become active participators in the lesson. Certain questions cause students to address their own conceptions. Other questions promote classroom discourse and conflict. And some questions are formatted to encourage the student to look at his or her own thinking and ask "why do I think this?" or "do I understand why another person has different point of view?" To utilize this technique effectively, I have decided when to introduce a scientist's viewpoint, how to determine the status of students' perspectives in relation to the scientist's perspective, and when to finalize the classroom discourse.

To promote problem solving, I develop and modify lessons to build on students' conceptual, mathematical and graphical understanding, utilize discovery activities and incorporate laboratory problem situations. I have found that many students do not connect the mathematical problems posed in science with the science concepts. I pose problems that require students represent their mathematical answers in multiple formats- conceptual, algebraically, graphically and pictorially. I feel it is important that the students not only solve mathematical problems in science, but also know what the answers really mean in the context of the situation. I also utilize discovery investigations to introduce a given topic. The activities are designed to lead the students through an investigation in which they have to determine the underlying concepts, relationships and patterns. These activities involve similar situations, use of technology and formal presentations of student findings.

The link between my teaching and student goals is effective assessment. Assessment needs to occur on a daily basis to determine when students are achieving my goals. There are four methods I use to assess student understanding: classroom discourse, student writing, application and traditional tests.

One of the primary forms of assessment that I use is to assess student understanding through classroom discourse, small group, or individual interviews on a daily basis. I critically listen to students' talk; namely their explanations of why, their justification for their answers, or their discussion during problem solving. I listen for students' ability to interpret the concept or make analogies. I make judgments about the status or level of students' understanding by listening to the language they are using as they reason through their own and others' viewpoints. This

type of assessment gives me the instant feedback that I need to alter or continue with the planned lesson. It also provides insight about individual students' progress with their learning.

Student writing has also become an important assessment tool for me. I often elicit students' ideas before the concept is introduced. Throughout a lesson, I will ask them to write about their current ideas on these questions. By reading their ideas, I can assess where they are at in their thinking and understanding of the given topic. Students write reflective papers at the end of major topics, focusing on their conceptions at the beginning of the topic, what their ideas are now, if and how their ideas have changed and what ideas they are still not comfortable with. This form of assessment has been very helpful for both the student and me, as it allows both of us to address the status of their understanding.

Another form of assessment is through the application of the concepts and mathematics. I utilize various problem situations, "experiment problems," and student presentations as a means of measuring understanding. This also provides indicators as to the students' level of integration of the science concepts with the mathematical and graphical representations and their ability to problem solve.

I incorporate a variety of questions for the traditional end-of-topic tests. One format that I have found effective is the use of multiple multiple choice questions. A situation is presented and statements or phrases are provided. The student has to decide if zero through all the phrases is/are correct. I also like to use situations where opposing viewpoints are given. The students have to access which viewpoint is correct and explain why it is true. But, most importantly, students have to explain why the other viewpoints are not correct—i.e., decide what is wrong with other's ideas.

Teaching Every Day

Effective teaching for me is to merge instructional strategies so students are anticipating instead of expecting the same routine. I draw from a variety of methods, tools and resources, with an end goal to personalize these resources to my students' needs. I incorporate problem solving skills and integration of mathematics with science as we approach each science concept.

The most valuable tool in my "instructional strategies" kit is the utilization of conceptual change ideas, problem solving methods and various forms of assessment. I have discussed many of the particulars in the "Student Goals" and "Teaching Goals" sections of this paper. My implementation of these techniques is the result of the introduction to these ideas in university coursework.

Problem solving and integration is largely from my involvement with graphing calculator technology and the interaction with our Calculus teacher. Certainly a resource that has enhanced integration of conceptual understanding with mathematical and graphical interpretation has been the use of graphing calculator technology. Through the use of the hand-held technology, I am able to ask students a higher level of questioning about relationships and patterns in the data because of the ease at which the data can be manipulated. I also interact regularly with our Calculus teacher to correlate what the students are learning in Calculus with what we are discussing in Physics. We conduct math-science projects, where students conduct investigations, then present their findings from both the math and science perspective. We have deemed this critical in helping our students understand the relationship between math and science and the application of mathematical understanding in the sciences.

Ultimately, the school schedule and course of study prescribes the amount of time that can be allotted to each topic. There are times when I know the status of several students' ideas is not where I want it to be, but I have to proceed. However, I strive to continually work with their ideas by recalling these ideas in classroom discourse or working with individuals before or after school. I often find this is one of the most difficult challenges in teaching science everyday – knowing what methods help student understanding and incorporating these methods in the daily school schedule.

Professional Development for Effective Teaching

When I reflect on what experiences and training has helped me the most, I truly feel one area stands in the forefront - being able to view and discuss classroom footage from master teachers' classrooms. My initial viewing of "A Private Universe" along with a ten-week teleconference from Harvard University focusing on

Conceptual Change teaching and learning had the most impact on my style of teaching and assessment. This is where my instructional strategy was truly "redesigned." Watching the videos, then discussing the content with other teachers, master teachers, and university faculty gave me insight as to what my students are thinking, why they hold certain ideas, and how to redesign my instructional strategy to address these issues. I strive to be involved in courses or sessions using this format. Really it becomes an assessment of my own teaching, as I have to interpret what I am watching, apply it to my students in my classroom setting, and critically evaluate the teaching effectiveness from a variety of perspectives.

Conclusion

Overall, teaching science everyday offers an array of opportunities to help students understand science and their thinking process. Students need an active voice and responsibility in their own learning. Teaching science effectively every day requires interaction with students through active listening and questioning. Through the use of well-designed instructional strategies and classroom formats we, as teachers, can help students achieve the goal of science understanding.

Science Teacher Licensure Requirements in Ohio

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(See Addendum)

What is Right and Wrong With Science Education?

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Introduction

The purpose of this study was to conduct a longitudinal study of a program designed for paraeducators enrolled in an Urban Preservice Degree Articulation in Teacher Education (UPDATE) Program. During the first year of the program paraeducators were exposed to mathematics content using constructivist instructional approaches: collaborative group work, problem solving, the use of manipulatives, and calculators. These user-friendly mathematics courses (reformed courses) offered at Springfield Technical Community College through the UPDATE Program, during Summer and Fall 1998, had a positive impact on paraeducators' attitudes toward mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999). Because of the limited availability of reform minded science instructors, during the second year of the program paraeducators were enrolled in a traditionally taught science course (a non-reformed course): lectures and note taking.

Inquiry-based instruction continues to receive considerable attention from both science and mathematics education reform movements. The National Council of Teachers of Mathematics (NCTM, 1989; 1991; 1995), the Mathematical Association of America [MAA] (Tucker & Leitzel; 1995), the National Research Council (NRC, 1996), and the American Association for the Advancement of Science (AAAS, 1993) advocate using a constructivist method of teaching, in which learners construct knowledge. Reformed teaching at the college level is particularly important for future K-12 teachers, because literature on teacher education posits that teachers tend to teach the way they were taught when they were students (Brown & Borko, 1992; Kennedy, 1991). Future teachers spend thousands of hours in classrooms watching what heir instructors do and develop beliefs about teaching based on their experiences. This is why it is so important that college level mathematics and science courses

should model the type of teaching that is consistent with the educational reform movement. College faculty should model "good teaching" that uses constructivist instructional strategies for pre-service teachers. Yet, many college math and science professors still continue to emphasize covering content using a traditional lecture and note taking approach.

Studies have been conducted that compare the difference between traditional and constructivist teaching methods using two different groups of secondary school students. In most of these studies, one group of students is exposed to traditional methods of science instruction while a different group of students is exposed to constructivist methods of science instruction (Chang, Chun-Yen & Mao, Song-Ling, 1998; Ertepinar & Geban, 1996; Geban, Askar & Ozkan, 1992; Gibson, 1998; Jaus, 1977; Mattheis & Nakayama, 1988; Padilla, Okey & Garrand, 1984; Purser & Renner, 1983; Saunders & Shepardson, 1987; Scheider & Renner, 1980; Selim & Shrigley, 1983; Shrigley, 1990; Wollman & Lawson, 1978). Overall, these studies conclude that inquiry-based science activities have positive effects on students' science achievement, attitudes toward science and school, cognitive development, laboratory skills, science process skills and understanding of science knowledge as a whole when compared to students taught using a traditional approach.

Much research has focused on comparing the two methods of instruction. However, in all of these studies two different groups of students were exposed to the two different instructional methods. Research that looks at the impact of the two different types of instruction on the same group of students has rarely, if ever, been conducted. In this study we had an opportunity to document the experiences of preservice teachers who were exposed to both types of instructional methods (constructivist and traditional approaches; reformed and non-reformed courses) and try to understand how instructional methods impacted preservice teachers' attitudes toward teaching and learning mathematics and science.

Mathematics and Science Courses

Three mathematics courses were offered at STCC during Summer and Fall 1998 (Elementary Algebra I, Elementary Algebra II (both pre-college level mathematics courses), and Math for Early Childhood/Elementary Teachers, a college level

mathematics course). All three mathematics courses were taught using a wide range of instructional strategies (e.g., collaborative group work, problem solving, the use of manipulatives, and calculators). This series of constructivist mathematics courses had a positive impact on paraeducators' attitudes towards mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999).

UPDATE paraeducators enrolled in a basic introductory college level Biology course during Summer 1999. This course was taught using a traditional lecture and note-taking approach (a non-reformed science course). The course is normally taught to over 300 community college students during each Fall semester. Typically five to six faculty members teach different sections of the Biology course. The faculty members work together to make sure that they are all covering the same factual information. They want all sections of the course to be consistent. The overall goal of the course is to establish some fundamental knowledge of cell biology: how cells are put together, how they operate, and what are the constraints on their operation. The focus of the course is to help student learn basic biological facts and concepts.

Participants

Sixteen UPDATE Scholars completed the three mathematics courses (Elementary Algebra I, Elementary Algebra II (both pre-college level mathematics courses), and Math for Early Childhood/Elementary Teachers, a college level mathematics course) during Summer and Fall 1998. They passed all three math courses with a grade of C or better. Fourteen of these UPDATE Scholars enrolled in Principles of Biology 102 during Summer 1999. Only twelve of the UPDATE Scholars passed with a grade of C or better.

All fourteen UPDATE students, who took the Principles of Biology course, were women. Two were African-American, five were Hispanic and seven were Caucasian. Eight were married, one was single, and four were divorced. Nine of these women had dependent children living at home. Thirteen of the UPDATE scholars started the UPDATE program in Spring 1988; one woman started the program during Fall 1999 (she had a number of transfer credits). For these thirteen women the Principles of Biology course was their 4th semester in the UPDATE Program and was their first science course.

Methodology

UPDATE Scholars enrolled in Principles of Biology 102 completed two questionnaires: an *Attitudinal Survey* and an *Instructional Strategies Survey*. The *Attitudinal Survey* (Gibson & Van Strat, 2000) contains 51 statements to which students responded on a Likert scale. That is, each item had five possible responses, ranging from "1-Strongly disagree" to "5-Strongly agree". Student responses to these 51 items were used to look for any changes in students' attitudes over time.

The *Instructional Strategies Survey* (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999) contains 15 instructional strategies to which students responded with one of the following five responses: "Didn't happen", "Happened and not helpful", Happened and somewhat helpful", Happened and very helpful", and "Happened and extremely helpful". Paraeducators' responses to this survey were used to determine what instructional strategies were used and whether the instructional strategies used were helpful to their learning of scientific concepts. In addition, this survey has several questions designed to gather information about how specific instructional strategies helped paraeducators learn.

Data Collection

The two survey instruments as well as focus groups and interviews were used to provide varied perspectives of the program. The *Attitudinal Survey* was administered twice: once during the beginning of the course, and once near the end of the course. *The Instructional Strategies Survey* was administered once near the end of the course. Both surveys were administered in class to all students present on that particular date.

In addition, a focus group with paraeducators enrolled in Principles of Biology 102 was conducted. The purpose of the focus group was to gather information from paraeducators about the overall UPDATE Program and specifically about the Biology course. Participation in the focus group was voluntary and no members of the STCC staff were present. The focus group was audiotaped for transcription purposes only. The session lasted about 90 minutes. In addition, an informal interview was conducted with the professor who taught the Biology course.

Results

To find out if there were any differences in UPDATE Scholars' attitudes toward science over time, a paired t-test was used to look at the items on the *Attitudinal Survey.* (Any p values less than .05 were considered statistically significant.)

A paired t-test showed that there was a statistically significant difference (p = .045) in UPDATE Scholars' attitudes toward teaching science between the beginning and the end of Principles of Biology 102 (Figure 1). UPDATE scholars over all attitude pre mean score was 2.71 and their post-mean score was 2.00. Paraeducators' attitudes toward teaching science became more negative after taking Biology 102.

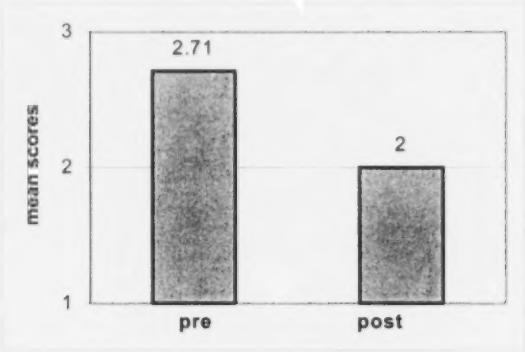

Figure 1. The idea of teaching science appeals to me.

Responses on the Instructional Strategies Survey and comments made by the paraeducators during the focus group revealed some possible explanations for this negative impact. Here are some examples of what UPDATE Scholars had to say about the Principles of Biology course:

- *This course was very demanding and challenging.*
- *This course was very stressful.*
- *The workload was overwhelming.*
- *The stress of constant test taking made many paraeducators not want to take any more science courses.*
- *Too much material was covered in this course, too fast.*

- *The professor, on numerous occasions, would try to explain science concepts to them using complex language that they could not understand.*

The way the course was taught may have caused a negative impact on UPDATE Scholars' attitudes toward teaching science. Paraeducators enrolled in this introductory Biology course were expected to memorize the basic facts about biochemistry and cellular biology. They were required to take many tests to demonstrate that they had indeed memorized this factual information.

The UPDATE Scholars said that this course showed them how frustrating it can be for learners to be judged by constant test taking. The focus group with UPDATE Scholars revealed that many did not look forward to taking any more science courses because of their negative experience in this introductory Biology course. The UPDATE Scholars said that they were not interested in memorizing a lot of scientific facts and information to pass a test to meet their College's science requirements. They said they really wanted to learn science and understand concepts, instead of just regurgitating facts and information.

The professor who taught the Biology course said that this course was designed to present straightforward factual information that people needed to master before they could have discussions or do anything else with the information. He/she felt that the best way to get this information across to students was by lecturing, as lecturing is an efficient way to transmit knowledge from the instructor to the student. The professor said that he/she realized that teaching in this manner was less interesting to students, but this course was designed for students to learn specific facts, such as, what cells are made up of and how they work. He/she admitted that this introductory Biology course was not designed to really convey the nature of scientific inquiry.

Conclusion

The three mathematics courses UPDATE students took during Summer and Fall 1998 were taught using a constructivist approach. This method of teaching had a positive impact on paraeducators' attitude towards mathematics (Gibson, Brewer, Magnier, McDonald & Van Strat, 1999). In addition, the data indicated that these instructional methods also helped paraeducators learn mathematics. Constructivist

teaching methods improved UPDATE students' attitudes toward mathematics and it also helped them learn mathematics. This user-friendly method of instruction was important to pre-service teachers developing good attitudes toward mathematics.

In contrast, Principles of Biology 102 was taught using a traditional approach (lecture and note taking). The data presented in this study indicates that the traditional teaching methods used in the Biology course had a negative impact on paraeducators interest in teaching science. It is unfortunate that the paraeducators had a negative experience in their introductory Biology course. Reformed college science courses that use constructivist instructional strategies, like the ones used in the three mathematics course the UPDATE Scholars took, probably would have had a very different impact on these future educators' attitudes toward teaching science.

Research has shown that prospective teachers' attitudes and beliefs toward mathematics and science are key influences on how they teach (Ball, 1990a, 1990b; Moreiri, 1991; Peterson, Fennema, Carpenter & Loef, 1989; Oshima, 1966; Roth-McDuffie et al., 1996; Schoenfeld, 1985, 1989; Silver, 1985; Strawitz, 1976; and Watters & Ginns, 1997). If we want teachers that can use constructivist instructional strategies to teach math and science then we must change the way that math and science is taught at the college level as well as the K-12 level. Unfortunately, traditionally taught college level math and science courses continue to perpetuate the belief that knowledge should be passed down from teacher to student and that learning involves memorizing facts and information. Students are seen as empty vessels waiting to be filled, and teachers should do the filling. Lecturing informs students what they need to know, and students listen and memorize what they have been told.

Many undergraduate science courses continue to be fact-laden, non-inquiry oriented with cookbook laboratories. Because many pre-service teachers learned science by attending lectures and taking notes, it is not surprising that they view science as a body of knowledge which they are expected to transmit to children. When pre-service teachers finally begin teaching science in their own classrooms, they will remember how they were taught. Many pre-service teachers have biased views about how science should be taught. In contrast, research supports the idea that pre-service teachers who participate in science courses taught using constructivist instructional methods (inquiry-based) will develop a positive attitude toward science,

and this may translate into their interest in teaching science in the elementary classroom. The goal is to prepare teachers who can encourage children to ask their own questions and to allow children to find their own answers, not to tell children a bunch of facts and information about science so they can pass a test.

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Redesign in Undergraduate Chemistry Curricula

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The Department of Chemistry at The Ohio State University, as one of the ten original departments, has a long and proud history in the education of students at all levels. This includes first-year college students who quake at the prospect of taking their first course in chemistry, other first year students who have had superb training in chemistry in high school, pre- professional undergraduates for whom chemistry will be central to their ultimate career, undergraduate chemistry majors who plan to pursue a career in our science, and Ph.D. candidates who choose to learn their craft from the world-class teachers/researchers on our faculty.

In the present discussion I will focus on our undergraduate classes, especially those at the introductory level, and the ongoing efforts to improve their effectiveness. In doing so, however, it is essential to provide some context for these efforts, both within the department and for the wider world our students will experience.

Departmental Mission

The most recent explicit statement of our mission appears in the Strategic Plan adopted by the faculty in July, 1996, after an extensive review of our program by an external panel of experts in chemistry.

> "***The mission of the Department of Chemistry is to provide a program of chemical studies worthy of national and international recognition for its accomplishments. Teaching is the essential tool we use to introduce students to the principles of the science, to guide professional chemists in the search for new knowledge, and to apply the knowledge of chemistry for the benefit of the citizens of Ohio, the nation, and the world. Learning is supported at all levels: students, staff, and faculty.***"

Chemistry plays a central role in helping students to understand a variety of disparate fields, including biology, medicine, agriculture, engineering, pharmacy, and consumer science. The application of these principles to problems outside of chemistry requires that students learn to think, rather than merely memorize a set of facts about chemicals and their reactions. Thus, we are committed to helping our students learn to analyze chemical data, to use these analyses to arrive at logical scientific conclusions, and to extend their critical thinking beyond the chemistry textbooks.

In a typical quarter, approximately 34 faculty members work with about 3500 students at the first- year-level, 1200 students at the second-year-level, 200 undergraduate chemistry majors, 217 graduate students, 40 post doctoral researchers, and a few visiting professors. All of these constitute the target audience of our teaching and learning program in the department. The task would be impossible, of course, without the help of about 57 full-time professional, technical, and clerical associates, as well as a large number of student employees.

Our Faculty: A Culture of Teaching and Research

At Ohio State, we often speak of the synergy between good teaching and good research. The culture of the Department of Chemistry is such that teaching and research are inseparable activities; excellence in both teaching and research is cherished and rewarded. One measure of our excellence is the large number of University-level awards for *both* teaching and research that have been received by individual faculty in the Department. Finally, the culture in our Department that fosters excellence in teaching *and* research is evident in an analysis of faculty that have received University awards for *both* activities. Since the inception of the OSU Distinguished Research/Scholar Award, there have been 12 faculty members University-wide who have received that award *and* either the Alumni Award for Distinguished Teaching or the Arts and Sciences Outstanding Teaching Award. Five of these dual teaching/research award recipients have been from the Department of Chemistry (including the current Department Chair)! No other department at OSU has had more than one such honored faculty member.

Evaluation of Teaching and Mentoring of Junior Faculty

The Department of Chemistry is deeply committed to using student evaluation as an important measure of the effectiveness of our courses. Most student evaluations in chemistry use detailed questionnaires developed in our Department over a period of thirty-five years. These questionnaires have been formulated for each major teaching area in the Department, and are designed to provide the maximum useful feedback to individual faculty members. A large number of faculty in the Department also use the OSU Student Evaluation of Instruction (SEI), contributing to the baseline data needed to make this an effective instrument. Many faculty also seek anonymous written comments from students on teaching aspects that are specific to the given course.

Training and Evaluation of Teaching Associates

The Department enjoys collaboration with about 155 graduate teaching assistants (GTAs) and about 35 undergraduate teaching assistants (SIAs). These students are given orientation programs to help them get started in their teaching support activities in laboratories and recitations. We also have a course offered during the summer, CHEM 701, designed to enhance the teaching skills of new graduate students as they enter our program. Each summer we work with about 70% of the new class of graduate students, involving about 50 students. The GTAs and SIAs work with lecturers and staff on a weekly basis to coordinate their supporting roles in the teaching program. They also get feedback from student evaluation of teaching in the same manner as faculty. Those who are rated highly by students and/or faculty receive small, but cumulative, pay increases.

The Teaching Challenges

The Department must maintain high standards for itself and for its students in order to fulfill the teaching mission and to prepare students for their future careers. Many students view chemistry as one of their more difficult subjects. Moreover, most students in our lower-division courses are taking chemistry only because it is required in their curriculum. Consider, for example, that in 1997 on the Columbus Campus there were about 6100 New First Quarter Freshmen. During that same year, we had a total of about 4100 students take one of the beginning courses in chemistry (101, 121,

or H201). Of that 4100 only about 50, on average, will become chemistry majors. Thus our *primary challenge in the general chemistry program* is to help prepare students for the as-yet-unknown chemistry-related tasks they will face in their future careers and for their role as responsible citizens in an increasingly complex world of technological compromises. This very real world leaves no room for grade inflation.

By its nature, chemistry is an experimental science. Thus, all the 100-level courses in chemistry include an extensive laboratory experience along with the lectures. The same is true of all the 200-level courses, although, for pedagogical reasons, the lecture and laboratory experiences in organic chemistry are taught as separate courses. One of the remarkable challenges in teaching undergraduate chemistry, especially at an institution as large as Ohio State, is to give each student a stimulating laboratory experience. General and Organic Chemistry laboratories depend on an extensive infrastructure of support, including Graduate Teaching Associates (GTAs), undergraduate Student Instructional Assistants (SIAs), full-time staff, laboratory space, and technical services. Both courses also make extensive use of televised pre-laboratory taped instructions, at a considerable expense. A 1998 UTS grant of $89,000 helped upgrade projectors in the 18 laboratories; a $56,000 grant in 1999 is permitting us to update the videotapes and convert them to a digital format for easier editing and for CD/WEB presentations. Upper division laboratory courses in Analytical and Physical Chemistry shift progressively to more independent work by the student, with increasing demands for specialized laboratory equipment and qualified teaching assistants. The importance of the undergraduate laboratory experience is reflected by a special allocation in 1997 from departmental Academic Challenge funds of $500,000 to upgrade and improve equipment in our undergraduate teaching laboratories.

Innovations in Teaching

The Department of Chemistry is constantly striving to implement new innovations in its teaching program. First, because chemistry is a dynamic, constantly changing field, we update lecture material every year to reflect new discoveries and new paradigms in chemistry. We also update laboratory course experiments, trying, whenever possible, to show students the excitement in new discoveries. A good

example is provided by the remarkable 1986 discovery of so-called high-temperature superconducting ceramics by scientists working in Switzerland. Within a year of this discovery (which led to a Nobel Prize), undergraduates at Ohio State were making these materials and studying their properties as part of our physical chemistry laboratory course.

Many new innovations in the teaching of chemistry at OSU involve the electronic delivery of teaching and learning materials via the Internet and World Wide Web. In 1995, the department made a dedicated commitment to develop a first-class WEB site, now located at ***http://www.chemistry.ohio-state.edu***. This site serves as a central location of information about the entire scope of departmental activities. It has also been helpful as a recruiting tool for prospective undergraduate and graduate students. Faculty in the department also have been awarded two UTS grants for $1000 to help develop different learning aspects of this site in general chemistry and in organic chemistry, as well as a BETHA grant for $53,280 to develop state-of-the-art tutorials for chemistry students. The results have generated invited presentations at the inaugural *OSU Best Practices Faculty Symposium* in May of 1997, to faculty in the College of Nursing, to science faculty at Columbus State Community College, and to the Board of Trustees in 1998. Many faculty and lecturers in the undergraduate program now use resources such as WebCT to distribute information to students on a timely basis, some of which must be restricted to selected audiences.

Resources for Students and Teachers

A faculty that is engaged in and committed to the teaching of chemistry is obviously the most important starting point for a successful teaching program in chemistry. In order to maximize the learning experience for our undergraduate students, the Department of Chemistry has developed a number of enhancements that allow the faculty to reach their maximum teaching effectiveness.

Support Services for Lecturers

For our large-enrollment classes in general chemistry and organic chemistry, the department provides considerable support to assist lecturers with scheduling, record keeping, coordination of teaching assistants, distribution of materials, and the organization and stocking of laboratories. The lecturers also have access to examples

of old exams (going back to 1908!), to a collection of test questions suitable for current exams, and to a generous supply of professionally prepared visual aids.

Lecture Demonstration Program

Our Department has a full-time staff member, Ms. Mary Bailey, who, as part of her duties, has developed efficient and dramatic demonstrations that can be performed in lectures, especially in the lower-division undergraduate courses. Some of these demonstrations involve very sophisticated and expensive apparatus that allow students the opportunity to see chemistry come to life before their eyes. Over the last 12 years, Ms. Bailey, with input and guidance from the faculty, has developed a demonstration program for our Department that we believe is as pedagogically useful and aesthetically spectacular as that at any other institution. In course evaluations, our students invariably comment on their enjoyment of the demonstrations, both for their learning value and because they can be flat-out fun! In the 1994-95 academic year, the Department performed approximately 2300 lecture demonstrations at an estimated cost of $16,000 for materials, supplies, and apparatus. In addition, the Department provides GTAs to work with Ms. Bailey in this program.

Learning Resource Center

We know that many students find chemistry a difficult and sometimes intimidating subject; consequently, we have established a number of resources to help them with their encounters. We have a "help room" which is open forty-five hours per week for all general chemistry students. This Center provides an opportunity for students to meet with individual graduate teaching assistants for personalized tutoring. It also provides about twenty computer stations, recently upgraded after ten years with funds from a UTS grant for $56,000, with exercises and questions they can choose and work through at their own pace. Many students are very concerned about the exams; therefore, we also make available copies of several previous mid-term exams that can serve as study examples for content, style, and length of exams.

Electronic and Internet Services

The Department of Chemistry prides itself in keeping up-to- date in technological developments that will have an impact on the effectiveness of our

teaching program. Currently, much research chemistry is performed using the Internet, and we have attempted to extend similar services to our students. All our instructors now use email as a means of facilitating discussion among class members and the faculty. Using our own time and resources, we have developed World Wide Web (WWW) home pages for courses that allow students ready access to course materials, such as solutions to homework problems and sample examinations. We have a number our GTAs who have developed strong interests in the development of these new resources; they enjoy learning more about the WWW and about HTML programming, and the experience they gain enhances their skills and marketability.

During Spring, 1995, a group of interested faculty and staff initiated a program designed to bring major resources for the study of chemistry at the undergraduate level to a WWW site in our department. It has permitted the development of a continuously-growing collection of resources on chemistry. These efforts were partially supported by small UTS grants and by a BETHA grant. Rather than describe all of the resources that we make available at this site, we encourage the Committee members to access it at **www.chemistry.ohio-state.edu/**, then follow the leads to 'undergraduate' and 'courses', and enjoy surfing through our programs!

In addition to providing information normally available in printed form, the WWW site has two study features that have been in place about two years: (a) a quiz bank and tutorials for general chemistry and (b) flash cards for organic chemistry. Both have been used by our students and by the larger 'student body' outside the university.

Televised Pre-Lab Lectures

These resources have proven their usefulness in our department over a period of about thirty years. The tapes presently in use were produced on-campus in 1986- 87 taking full advantage of color, sound, animations, and demonstrations on the macro and micro scale. The primary leaders in this version of the tapes were Dr. Robert J. Ouellette and Ms. Mary H. Bailey. They worked closely with personnel in the Office of Learning Resources in the taping, editing, and production of the final master and copies of the tapes. We broadcast appropriate tapes at the beginning of each laboratory period using on-site facilities, with follow-up additions and corrections presented by the laboratory teaching assistant. The pre-lab tapes are considered an

essential part of each student's preparation; in fact, if a student misses the tape by being late to the lab, they are required to view the tape before proceeding with the experiment.

At the present we are updating these existing instructional tapes. The production of any new pre- laboratory presentation is a process that must combine a number of elements. The technical content of the presentation must be scripted, and then combined with digital audio and video segments, animations and still photographs. The skills necessary to develop these individual elements are available to us from Columbus and Lima Campus Chemistry personnel, UTS personnel, and faculty and graduate students from ACCAD. These strands are being pulled together into a cohesive and powerful whole using a digital multimedia authoring program (such as Authorware). A great advantage of these developments lies in the ease with which subsequent modifications to the presentations may be made. Once in digital form, all of the media elements in the presentation may be edited and rearranged where appropriate, without the need to re-edit or re-shoot videotape as has been necessary with the present analog videos. In this way, the presentations will more easily retain consistency with the experimental procedures that the students actually perform.

These formats offer new and exciting opportunities to target a significantly broader use of these instructional materials. Unlike the present videotapes, which are simply viewed in class before a particular experiment, we envision a number of additional methods for broadcast of these multimedia presentations. Two new methods, in particular, will be developed: WEB-based distribution and CD-ROM distribution. An obvious advantage of these new mode(s) of delivery is that students will be able to view the pre-lab presentations in their own home or using Chemistry department computer facilities before coming to lab. We also plan to build in additional interactive elements, which will engage the student and result in better *preparation* for the laboratory. Ideally, these would require responses from the student which demonstrate an understanding and assimilation of the material, thus making the entire laboratory experience more enjoyable and beneficial to long-term retention of concepts, laboratory techniques, and data manipulation. These tutorial aspects will also be invaluable in strengthening links between laboratory and lecture material in the minds of the students.

Undergraduate Research

While formal structured classroom instruction educates students in the well understood aspects of chemistry, it fails to convey the nature of the process of discovery of new knowledge and new insights, the importance of individual enterprise and creativity, and the mindsets of its practitioners. Research is, of course, an integral part of the graduate teaching experience in chemistry. In addition, *we are committed to helping our undergraduate students obtain a true research experience.* In fact, it is the philosophy of our Department that research is the defining experience of undergraduate education. Typically 30 undergraduates are engaged in research projects at any one time. During summers, undergraduates come to the Department from all over the country and some from abroad to work on research in collaboration with our faculty. These summer activities are funded in part through the NSF Research Experience for Undergraduates program. Our undergraduate students find their research experiences to be invaluable.

Conclusion

The challenge of redesigning and revitalizing the chemistry curriculum must be addressed as an ongoing task rather than a solution to a single problem. In this process it is imperative that faculty who are committed to leadership in research and teaching be among its authors. Chemistry at the university level in particular, requires a preparation in technical literacy with an ever-changing world of information, resources, and decisions. It is an endeavor worthy of our highest commitment.

Session II.

Turkish, Korean and Israeli Redesign in Action, Lessons Learned along the Way, Assessment Efforts

Informing Science Teacher Education Redesign in the USA with Knowledge of Practices in Germany and Japan

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Prompted by the results of the Third International Mathematics and Science Study (TIMSS) and other international assessments of student achievement, science educators in the USA have begun to vigorously investigate the systems of science teacher education in countries around the world. This summary describes science teacher education practices in Germany and Japan that have the potential for informing science teacher education redesign in the USA. To establish credibility for our descriptions and recommendations, both the systems of schooling in Germany and Japan and the presenters' experiences in these countries will be discussed. The science teacher education systems of Germany and Japan are of particular interest because of the academic rigor associated with school science in these countries and the fact that German and Japanese students regularly score high on international comparisons and have historically made significant scientific contributions as adults. Further contributing to the interest in the science teacher education systems in Germany and Japan is the economic strength of both countries and the professional status of teachers within the German and Japanese societies.

Presenters' Knowledge-Base and Experiences

Describing teacher education practices in Germany and Japan and suggesting how they might inform the redesign of science teacher education in the USA requires some understanding of the education systems of both countries and their unique cultures.

Both of us are involved in long-term study of the teacher education systems of Germany and Japan. Tom is working with German science educators at the Institute fur die Pädagogik der Naturwissenschaften (IPN) at the University of Kiel and was a

guest professor at the IPN in 1997. Joe is co-director of a three-year international science education research project jointly funded National Science Foundation (NSF) and the Japan Society for the Promotion of Science (JSPS). He recently returned to the USA after four months as a visiting professor at the Center for the Study of International Cooperation in Education at Hiroshima University.

Overview of Schooling and Teacher Education in Japan and Germany

The organizational framework of Japan's schools aligns closely with that of the USA. This conformity results mainly from USA mandated educational reforms during the post war administration of General Head Quarters (GHQ). Six years of compulsory elementary education leads to three years of compulsory lower secondary school followed by three years of upper secondary school. Students who wish to go beyond the nine compulsory school years must pass secondary school entrance exams. About 96 percent of lower secondary school graduates go to upper secondary school and 45 percent of these graduates go on to college. While school organization patterns appear similar to those in the USA, Japan's highly centralized system of educational governance differs sharply from the USA model of local governance.

Teacher education in Germany is closely aligned with the organizational structure of German schools. *Kindergarten* attendance for children ages 3 to 6 is voluntary. The kindergarten serves a child care and socialization function (Eurydice, 1991). At the age of 6, pupils enter *Grundschule* or primary school. After four years of school attendance, parents in consultation with teachers decide what type of secondary school their child will attend. The child's achievement and motivation toward school work are weighted heavily in the decision.

About one-third of German children attend each of the three types of secondary schools: *Hauptschule, Realschule and Gymnasium* (Ries & Böhme, 1996). Students interested in working as skilled laborers or in crafts such as carpentry or auto mechanics go on to a Hauptschule. They complete their studies at the end of grade 9 and then go on to serve a three or four year apprenticeship. Students wishing to pursue a careers such as nursing or work as a bank clerk or secretary will attend a Realschule after primary school. Schooling for these students continues through grade 10, with students then opting to enter either an apprenticeship program or a

vocational college for further technical education. Students who wish to become teachers must go to a Gymnasium through grade 13. The Gymnasium curriculum includes German language, mathematics, biology, chemistry, physics, geography, music, art, sport, and two foreign languages. During the last three years at the Gymnasium, students may choose to pursue an in-depth introduction to academic study in one of three areas: language and literature; social sciences; or mathematics, science and technology. With their graduation certificate, the *Abitur*, these students may go on to university or college.

Teacher education is consider an academic career track in Germany and is available only at universities or teacher training colleges. Grundschule and Hauptschule teachers are educated at colleges of teacher education where they study for a minimum of three years. Their studies typically involve 98 semester hours of course work in three school subject areas (70-76 semester hours), with a healthy dose of education, psychology and sociology (22-28 semester hours) (Döbrich & Kodron, 1992). These teachers also do at least one week of field-based work each semester, plus two blocks of four weeks and one of eight weeks toward the end of their studies, all supervised by university mentors. Realschule teachers also study in colleges of education. They typically engage in in-depth study of two school subjects (80 semester hours) and education, psychology and sociology courses (18 semester hours) (Döbrich & Kodron, 1992). Prospective Realschule teachers have multiple school-based experiences similar to Grundschule and Hauptschule teachers.

Gymnasium teachers are educated at universities, and take from four to seven years to complete their studies. They study two subject areas in the content departments of the university (120-130 semester hours), theory of education in the department of pedagogy (8-18 semester hours), and participate in two four-week unsupervised school experiences (Döbrich & Kodron, 1992). After completing university studies, prospective gymnasium teachers participate in a two year period of induction that is administered by a state agency, the Institute for Practice and Theory in School (IPTS).

Innovative and Confirming Practices in Science Teacher Education

Our work in both countries enables us to describe what we consider to be

innovative and confirming science teacher education practices. Innovative practices are those that we have observed in Germany and/or Japan that are not commonly followed in the USA. We describe them as innovative practices because we believe they hold promise for improving the current state of science teacher education in the USA. Confirming practices are those that tend to confirm, or at least provide support for, science teacher education practices currently favored or gaining favor in the USA. While we use the terms innovative and confirming to categorize the practices we have come to understand, we recognize that these practices do not stand alone in isolation from the landscape of professional practice present in these countries. Cultural differences must be considered when discussing the use or adaptation of any German or Japanese science teacher education practice in the USA.

Innovative Practices

Cooperative Student Teaching

In contract to placing a neophyte in a single classroom with a single cooperating teacher, student teaching for Japanese prospective teachers involves extensive collegial interaction. They plan together, observe each other teach lessons, and engage in collaborative critiques of each other's teaching. The rationale for this practice is that a collaborative team approach will better prepare reflective teachers. Collaborative student teaching also tends to guard against the physical and intellectual isolation that Goodlad (1991) noted as a serious flaw in the traditional approach to student teaching in the USA.

Primary and Secondary School Experience for Prospective Secondary Teachers

Two school-based experiences are part of the university education of prospective secondary (i.e., Gymnasium) science teachers in Germany. Each experience lasts for four weeks and is done when university classes are not in session. One is in a gymnasium and the second is in a primary school. The primary school experience is intended to help the prospective teachers learn about children and their early educational experiences. It is presumed that some knowledge of the science content children learn in the primary grades and how science is taught by primary grades teachers will enhance the effectiveness of prospective gymnasium teacher as they work with adolescent learners in the upper grades.

Secondary teacher education programs in Japan require their preservice teachers to observe classes in elementary and lower secondary schools. As of this year, the Ministry of Education (Monbusho) also requires that all preservice teacher education programs offer opportunities for prospective teachers to visit schools that work with special needs students and community service centers that work with the elderly.

Extensive Professional Development During Teacher Induction

Professional development begins with the first days of employment for beginning science teachers in both Japan and Germany. In Japan, new teachers have ninety days of inservice education during their first year on the job. The new teacher works for sixty days with a mentor, who provides guidance that is immediately relevant to the teacher's responsibilities. Both are assigned reduced teaching loads to ensure that the beginning teacher receives the mentoring needed to be successful. The remaining thirty days of inservice introduce the new teacher to wider concerns of the community as well as more formal lectures on teaching and learning. During the mentoring sessions that are spread across the school year, a part-time teacher (who is often a retired teacher) is hired to cover the classes of both the beginning and mentor teachers.

Similarly, beginning teachers in Germany participate in an induction experience (called *Referendariat*) after completing university studies. This induction experience typically lasts from eighteen months to two years. During the induction period, the teacher is paid about half the salary of a full-time teacher and teaches a reduced load under a mentor's supervision. When not teaching, the beginning teacher participates in seminars at the state's teacher training institute. The seminars address issues of pedagogical content knowledge, classroom management, and learning theory.

Confirming Practices

Emphasis on Content Knowledge

Study in the content areas that one will teach is the primary focus of German teacher education at either university or teacher training college. German students preparing to teach science at the Gymnasium take more than twice the number of semester hours of science content course as students in the USA preparing to become secondary science teachers. Moreover, there are no general education requirements

for university students studying to become Gymnasium teachers. Coursework comparable to that taken by university freshman and sophomores in the USA is completed prior to university admission. Only young adults with their Gymnasium graduation certificate, the *Abitur*, may go on to university. Likewise, German students preparing to teach only science in the Realschule and Hauptshule will also complete more hours of science coursework that prospective secondary science teachers in the USA. Eighty percent of a prospective Realshule teacher's coursework and seventy-five percent of a prospective Hauptschule teacher's coursework is in the content areas that he or she will teach.

Japan employs an "open" approach to teacher certification. This approach allows a student in a science major (or applied science major) the opportunity to earn a lower secondary/ secondary teaching certificate within a four year undergraduate university degree program. This "open" approach often means little time is available for pedagogical courses or field experiences. It often means large student enrollments in the few required education courses. Science education methods courses at some universities may enroll as many as 300 students in a class. The school practicum experience may be as short as two days and student teaching experience, two weeks. This lack of practical school experience is partially compensated by an intensive induction year in which new teachers take part in ninety days of inservice training. In both countries, knowledge of the subject is of utmost importance, with the understandings and skills associated with teaching developed only after mastery of the content to be taught.

Emphasis on Pedagogical Content Knowledge

The need for teachers to understand how to help students learn science is emphasized in teacher education coursework and induction experiences in both Germany and Japan. In Germany, one-half of the induction period seminars are content specific and often tied directly to school curriculum. For example, biology teachers would attend two or more seminar sessions on teaching genetics, while chemistry teachers would attend sessions on teaching students how to balance chemical equations. The scheduling of these sessions is such that a teacher whose content concentrations include both biology and chemistry would be able to participate in both sets of seminars.

As part of the induction program in Japan, recently hired teachers are provided a mentor teacher who meets with them two days a week. These are experienced teachers who are currently teaching the same subject or retired teachers who have taught that subject in the past. New teachers spend thirty days at a district teacher center where they also focus on subject specific pedagogy. Professional development beyond the induction year often employs observation of other teachers in their classroom. This observation is followed by open discussion about what happened in the class and how the lesson could be improved.

Guidance Provided by National or State School Curricula

The teacher education curriculum in Japan is guided by the content that students are expected to learn. This content is dictated by a national curriculum. The Monbusho maintains close supervision over the curriculum, and provides the major funding for schools. The Monbusho revises the national curriculum every ten years and controls and regulates most areas of education including textbooks, examinations, and the preparation of teachers. Japan's national curriculum outlines what students are expected to accomplish during each year of study. The Monbusho allows schools and local boards of education to modify national curricular guidelines in ways that are appropriate for the local condition. However, regional boards of education typically tend to strictly interpret Monbusho guidelines, making few adjustments (Stevenson & Nerison-Low, 1997). National assessments are based on the national curriculum and ensure that the planned curriculum is implemented.

Similarly in Germany, what students are expected to know and be able to do is dictated by the state (or Länder) curriculum. Only minor differences appear in the science curricula among the states. Those responsible for science teacher education are very aware of the state's curriculum and use it to guide their work with beginning teachers.

Redesigning Secondary Science Teacher Education

The innovative practices observed in both Japan and Germany offer guidance for the redesign of secondary science teacher education in the USA. First, we recommend that science teacher education programs consider placing student teachers in schools

as collaborative teams rather than as individuals. Teams of student teachers could be assigned to work with a single mentor teacher or work with two or more science teachers at one school. A possible outcome of student teacher teaming is the development of teacher learning communities that function to improve science teaching and learning. A pilot program of paired student teachers is now underway in the Science Education Department of the University of Georgia. A study associated with the pilot project is looking at "border crossings" that are negotiated by participants as they move from an individualist perspective to a more collaborative view of teaching.

We also recommend that secondary science teacher education programs consider early field placements that put prospective teachers in contact with elementary students and teachers. Placements of this type will provide prospective secondary teachers with insights about the nature of science learning experiences in the early grades. The insights gained through such placements will serve to sensitize the participants to children's science learning needs and the demands of the elementary school learning environment. It will also inform them about how they might best be able to build on children's early science learning experiences. Care must be taken when attempting to secure elementary school placement for prospective secondary science teachers. To avoid working at cross purposes and disrupting existing partnerships, university colleagues in elementary education departments should be consulted as the first step in establishing elementary field placements for prospective secondary teachers.

The science teacher induction programs functioning in both Germany and Japan serve to make preservice and inservice education an almost seamless process. Undergirding these programs is the recognition that science teachers need sustained assistance during the first years of their careers in order to become successful professionals. Characteristics of these programs that should be considered in the USA include making professional development part of the workload of beginning teachers, adjusting the teaching loads of those teachers who mentor beginning teachers, and engaging beginning teachers in regular and meaningful seminars or teaching institutes. An additional consideration that demands attention is deciding who is responsibility for teacher induction. In contract to the well organized structures in place in both Germany and Japan, science teacher induction in the USA is all to often a hit-or-miss

affair. The needs of beginning science teachers must be provided for in any systematic way.

Practices in Germany and Japan confirm the importance of both content and pedagogical content knowledge for science teacher success. In recent years, many university science teacher education programs have increased the number of required science content courses. Today science teacher candidates at many universities in the USA take as many, if not more, science courses than science majors. At the same time, the demand for science teachers has resulted in many states reducing the number of education courses required for teacher certification and establishing special fast-track routes to teacher certification. These actions have the potential for producing teachers who know science but are not equipped with the understandings and skills need to help students learn science. Attention need to be directed toward ensuring that pedagogical content knowledge remains a central elements of science teacher education in the USA.

Support for the science education standards movement in the USA and the guidance it provides science teacher education is also found in the practices observed in both Germany and Japan. The National Science Education Standards and the Project 2061 Benchmarks in many ways have led to an unofficial national curriculum in the USA. The Standards and Benchmarks have become extremely influencial in the education of science teachers. Their influence is certainly evident in the NSTA standards for science teacher education.

There is much that can be learned from science teacher education practices in Germany and Japan. In this summary, we have described both innovative and confirming practices that we believe can inform the redesign of science teacher education in the USA. When contemplating the redesign of science teacher education in the USA based on practices observed in countries like Germany and Japan it is important to consider the cultural milieu that will certainly affect their successful implementation.

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Redesigning the Science Teacher Education Programs in Turkey

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Introduction

In countries with a high ratio of young population like Turkey, education is an area, which is given high priority for training qualified manpower. Therefore, training qualified teachers who would educate the young population is important for a rapid economical growth and social development.

Throughout the history of Republic of Turkey many reforms have been made in the pre-service teacher training programs. However, these efforts were not adequate to meet the needs of qualified teachers in the country. Especially, in 1990's teacher training programs in Turkey were behind the changes in teacher education of contemporary world. These problems were criticized in terms of quality and content of courses, insufficient teaching practice period and inadequate number of primary and middle school teachers. In order to remedy these problems, it has become obligatory to change the teacher education programs.

In 1996, The Higher Education Council initiated a joint project to redesign teacher education programs. The purpose of this paper is to present information about the new science teacher education programs and reasons of redesign from historical perspective.

The History of Science Education Practices in Turkey

Middle School Science Teacher Training Programs (6-8th grades)

The first institute preparing secondary school teachers was "Middle Teacher School", which was opened in 1926-27. This school was developed with adding more

divisions at the end of 1940's and became responsible for preparing middle school science teachers. Because of the need of middle school science teachers, the number of these schools was increased. In 1967, the period of the training program was increased from two to three years and these programs were called as " Education Institutes." In 1978, Education Institutes were changed to four-year " High Teacher School" which trained both middle school and high school science teacher. After this reform, there had not been any institution training science teachers particular to middle school science courses until 1998.

In 1982, High Teacher Schools were rearranged under the roof the universities and called Colleges of Education whose graduates mostly prefer to work as high school teachers. The importance of the need of middle school science teachers had been neglected.

High School Science Teacher Training Programs (9-11th grades)

Until 1982 "High Teacher Schools" had trained high school science teachers. Since 1982, Colleges of Education have had the responsibility for high school science teacher education. In order to be accepted to the College of Education, students graduated from high school had to pass the "University Selection and Placement Examination." Depending on their choices and the points they earned on this examination, they were placed to the Department of Science Education. They were trained for the teaching profession through course in three fields –general knowledge, subject matter knowledge, and pedagogical courses. Department of Science Education had offered both subject matter and pedagogical courses.

The Need To Redesign Science Teacher Education Programs: Problems And Obstacles

There had been radical changes in science teacher education programs for the last fifteen years. Despite these changes, the science teacher education programs could not meet the needs of qualified teachers due to the inappropriate policy.

After the Colleges of Education had taken the responsibility of science teacher education in 1982, instructors were appointed from the Departments of Science to the Colleges of Education because of the insufficient number of faculty members in

education. Since these faculty members had an academic background in subject matters they had focused on subject matter based studies instead of studies in science education. The resources of the Colleges of Education had been used for graduate studies in the field of science. Colleges of Education offered the same science courses with the Department of Science. That is, they duplicated the same work. As instructors focused on subject matter instead of education, previous science teacher education programs emphasized the notion that " the more knowledge the teacher has the better the teacher can teach."

Because of the poor collaboration between The Higher Education Council, which is responsible for training science teachers and The Ministry of National Education, which is in charge of appointing these teachers, there had been graduated more high school science teacher than needed. On the other hand, there were not enough primary and middle school science teachers to meet the need of the country. Thus the students who were graduated as high school science teacher were appointed as primary school teacher. Therefore, candidate teachers lost their motivation during the training period.

One of the criticized aspects of the previous science teacher education programs was their curriculum. The curriculum of the previous programs lacked adequate intern experience in practice schools. In order to get teaching certificate, the students were only required to observe a classroom for a month. Moreover, there were not pedagogical courses such as classroom management and instructional technology, which could help them teach effectively.

The New Design of Science Teacher Education Programs

Since the flow of information is the most valuable product for all over the world, training qualified teachers is one of the high priority subjects in all countries. Due to the problems explained above Colleges of Education in Turkey had not been able to meet the need of highly qualified teachers. Therefore, restructuring the pre-service teacher training system had become a necessity. In 1996, The Higher Education Council initiated "Pre-service Teacher Education Project" which was funded by the loan from the World Bank (YOK 1998a.) The Higher Education Council and The Ministry of National Education have worked collaboratively to re-design teacher

education programs in Turkey. In 1998, Colleges of Education started to implement the new curriculum to train pre-service teachers. (OSYM. 1998)

Before the re-organization, science teachers graduated from the Department of Science Education had taught 6 – 11th grade students. After the redesign, science teacher programs were divided into Elementary Science Teacher Education (6-8th grade science teacher)-under the Department of Elementary Education-and Secondary Science Teacher Education (9-11th grades science teachers) – under the Department of Secondary Science and Mathematics Education. In order to be a grade 6-8 science teacher, a senior high school student has to pass "Student Selection and Placement Examination." Students enrolled in the Elementary Teacher Education programs have to complete the program in four years to get a Bachelor degree. Throughout the program students must take both science courses from the Department of Science and pedagogical courses from the Department of Educational Sciences and the Department of Elementary Education (YOK, 1998b)(see Table 1). On the other hand, in order to be a secondary science teacher students have to earn a non- thesis master degree. This program has two different implementations, one lasts 5 years and the other lasts 5,5 years. In the first implementation, students enrolled in the Secondary Science Teacher Education programs first have to study 3,5 year at the Department of Science and then take pedagogical courses for one and a half year. In the second implementation, students who already have a Bachelor of Science degree have to complete pedagogical courses in one and a half year to receive non-thesis master degree (YOK, 1998a; Bulut, 1999). The list of course offered is presented in Table 2.

Table 1. Elementary Science Education Program (Minor: Mathematics Education)

Semester 1	T	P	C
Physics I	4	2	5
Chemistry I	4	2	5
Mathematics I	4	0	4
Principles of Kemal Ataturk I	2	0	0
Turkish I: Written Expression	2	0	2
Introduction to Teaching Profession	3	0	3

Table 1. Elementary Science Education Program (*Continued*)

Semester 2	T	P	C
Physics II	4	2	5
Chemistry II	4	2	5
Mathematics II	4	0	4
Principles of Kemal Ataturk II	2	0	0
Turkish II: Oral Expression	2	0	2
School Experience I	1	4	3
Semester 3			
Biology I	4	2	5
Chemistry III	2	0	2
Mathematics III	4	0	4
Computers	2	2	3
Foreign Language I	3	0	3
Developmental Psychology and Learning	3	0	3
Semester 4			
Biology II	4	2	5
Physics III	2	0	2
Chemistry IV	2	0	2
Mathematics IV	4	0	4
Foreign Language II	3	0	3
Curriculum Planning and Evaluation	3	2	4
Semester 5			
Physics IV	2	0	2
Biology III	2	0	2
Laboratory Applications in Science I	2	2	3
Mathematics V	2	2	3
Instructional Technology and Material Development	2	2	3
Elective I	3	0	3
Elective II	3	0	3

Table 1. Elementary Science Education Program (*Continued*)

Semester 6			
Biology IV	2	0	2
Teaching Mathematics	2	2	3
Laboratory Applications in Science II	2	2	3
Classroom Management	2	2	3
Special Teaching Methods I	2	2	3
Elective III	3	0	3
Elective IV	3	0	3
Semester 7			
Science, Technology and Society	3	0	3
Special Concepts in Science I	3	0	3
Biology V	2	0	2
Evaluation of Subject Matter Course Books	2	2	3
School Experience II	1	4	3
Special Teaching Methods II	2	2	3
Semester 8			
Special Concepts in Science II	3	0	3
Counseling	3	0	3
Practice Teaching	2	6	5
Elective V	3	0	3
	Total Credit Hours		148

Table 2. Courses for the Three-Semester Complement to Earn a Master's Degree.

Semester 1	T	P	C
Introduction to Teaching Profession	3	0	3
Developmental Psychology and Learning	3	0	3
Curriculum Planning and Evaluation	3	2	4
Special Teaching Methods I	2	2	3
School Experience I	1	4	3

Table 2. Courses for the Three-Semester Complement to Earn a Master's Degree. (*Continued*)

Semester 2			
Instructional Technology and Material Development	2	2	3
Classroom Management	2	2	3
Special Teaching Methods II	2	2	3
School Experience II	1	4	3
Elective I	3	0	3
Semester 3			
Evaluation of Subject Matter Course Books	2	2	3
Counseling	3	0	3
Practice Teaching	2	6	5
Elective II	3	0	3
	Total Credit Hours		45

Field experience is a very important part of curriculum to prepare candidate teachers, who can combine theory and practice. This requires that College of Education and Practice School to work collaboratively and share responsibilities. However, previous teacher education programs have neglected teaching practice. In the previous teacher education programs, as a requirement of the teaching practice course students have to teach only in 40 minutes class period after observing an experienced teacher for 20 hours. The redesigned teacher education programs emphasize methods of teaching, practice, and collaboration between schools and the Colleges of Education. Student enrolled in the new programs have to take three new courses which are "School Experience-I", "School Experience-II" and "Practice Teaching" through which it is aimed to develop teaching skills and provide field experience in classroom observation, organization and management of schools, and examination of materials. The Higher Education Council signed a protocol with The Ministry of National Education in 1998 to improve the partnership and coordination between schools and Colleges of Education. According to this protocol, partnership group, which consists of faculty member and experienced teacher, will share the

responsibility of teaching the practice courses (YOK, 1998c).

Managing the classrooms is one of the important problems that novice teachers face with. In contrast to the previous teaching training programs, the new programs include "Classroom Management" course to enhance the efficiency of teachers in classrooms (YOK, 1998a).

Teaching profession requires using technology and teaching and learning materials effectively. One of the courses added to the new program is "Instructional Technology and Material Development". In accordance with the "Pre-service Teacher Education Project" teaching and learning materials and equipments, such as computers, video-projectors, and overhead projectors, were sent to all Colleges of Education.

Since the number of the qualified faculty members in the field of education has been limited in Turkey, Colleges of Education used to meet the need of staff with the faculty members from the Department of Science who used the sources of Colleges of Education for doing research in science instead of science education. According to the new programs, students will take courses related to the subject matter from the Department of Science not from the Colleges of Education. Colleges of Education will be charged with offering pedagogical courses. Moreover, to meet the needs of qualified faculty members of teacher education programs The Higher Education Council and The Ministry of National Education have allocated 750 scholarships for master and doctoral studies in developed countries.

Because of the poor collaboration between The Higher Education Council and The Ministry of National Education, more than enough science teachers have been graduated while there was a need for elementary school teachers. After the reorganization, The Ministry of National Education will determine the number of teachers needed in all branches and The Higher Education Council will decide the number of students enter the Colleges of Education accordingly. Moreover, redesigning allows pre-service teachers to be trained on more than one subject. For example, students enrolled in Elementary Science Teacher Education programs have to choose Elementary Mathematics Education program as a minor. Trough this structure students graduated as a elementary science teacher can also teach mathematics whenever there is a need in their schools for mathematics teachers.

Conclusion

In this paper, we discussed the historical perspective of science teacher education system during the republic period, problems and obstacles of the previous teacher education programs and the new science teacher education programs.

Before the reorganization of the programs it was obvious that the teacher education programs were not able to meet the needs of the country due to the inappropriate policies. It is expected that all these changes made in teacher education programs will remedy the problems caused by the previous programs.

The need of middle and secondary school science teacher will be met with the graduates of the Colleges of Education according to the number of teachers determined by the Ministry of National Education. After redesign the resources of Colleges of Education will be used for only educational research and studies. The new programs will have more courses based on practice and the candidate teachers will be familiar with the actual class environment before the graduation. The students having doctoral degree in developed countries will be the instructors in the college of education. They will increase the quality of instruction in Colleges of Education when they return to the country.

The reorganization of the teacher education programs is a continuous process. In order to ensure their efficiency, the new programs should be continuously evaluated and they should be improved by taking the changing conditions of the world into consideration.

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Reforming Science Teacher Education in Korea

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Introduction

Korean education has grown rapidly since the Liberation in 1945. A drastic increase in enrollment rates has caused the corresponding boost in the numbers of schools, teachers, and facilities. The expansion of Korean education contributed to lowering illiteracy rates and providing well-trained manpower for industrialization. The strong zeal for education among Koreans that cannot find a match anywhere else in the world must be the most important driving force behind the rapid economic development of Korea (OECD, 1996).

Education policy in Korea has been changed several times in order to meet society's changing needs. These educational reforms have focused on the changes in entrance examination system and national curriculum with the basic skeleton of 6-3-3-4. The recent educational reform shows overall renovation in educational system. Especially, teacher education has emerged as one of the big issues with respect to the qualification of teachers. Its urgent thing is to prepare teachers who have a strong sense of commitment to teaching (MOE, 1999).

Therefore, some policies have been tried to foster well-qualified teachers. Comprehensive evaluation of pre-service teacher program and employment test for public school teachers are adopted as the important reforms in national policies for teacher education. This paper focuses on the corresponding reforms in science teacher education after introducing a brief history and current system of science teacher education in Korea.

Brief history of science teacher education in Korea

The first formal educational institute appeared in the AD. 4th century in Korea (Weidman & Park, 2000). However, it was in the 20th century that the system for preparing teachers including science teachers was established. Until then, most education had been focused on the humanities such as reading Confucian classics and developing composition skills. Not only that, there was no teacher education system. Education in scientific technology was restricted to those who pursued technological apprenticeship rather than to the common people. The first institute that characterized western educational system was established in 1876 and a few Koreans who studied in China as well as some Americans took charge in science education. In 1895, Hansong School of Education was open to satisfy the demand for teachers, but its curriculum was the same as that of secondary school at that time. Unfortunately, education for Koreans was not normally pursued during the era of Japanese rule.

After the Korean liberation from Japanese rule in 1945, the first college of education was built as a result of integration of two schools of education in Seoul under the control of the US military government. Also, two other schools of education outside Seoul were transformed to national colleges of education with 4-year curriculum for preparing secondary teachers. The number of teachers was not up to the national sudden increasing demand, so, a total of 12 temporary institutes for teacher education were run for 10 years (1947 to 1956). In order to broaden the source of teacher preparation, a lot of education courses have been open in general colleges since 1955, several private colleges of education since 1965, and graduate schools of education since 1967 (MOE, 1998a). In the process of innovative economic development, the government emphasized science education. However, the problem was that many science teachers moved to industrial companies, consequently, the quota of institutes for preparing science teacher was increased to a great extent.

Since 1980s, demand for teachers has not increased any more whereas the number of teachers from institutes for teacher education has kept on increasing. The over-supply of secondary teachers has come to be a serious problem. As a result, the argument over quality of teachers has emerged as a social issue. Unsystematic programs in pre-service teacher education have been criticized and also better approaches to improve teacher education program have been discussed. In addition,

the priority given to graduates from national college of education was abolished in 1990 and open competition test has been held for selecting public school teachers up to now.

Current system

Preparation

Institutes

Approximately 70 out of 158 universities have secondary school pre-service science teacher programs under the approval from Ministry of Education. Three types of these programs can be identified: Departments of science education in college of education; education courses in college of natural science, engineering, or agriculture; and graduate school of education. Colleges of education in 16 universities -- 11 public and 5 private -- take an important part in conducting pre-service teacher programs. Education courses of 171 departments at college of science, agriculture, or engineering in 56 universities take a supplementary role. 71 Graduate schools of education play a mixed role in advanced training of in-service teachers and preparation of pre-service teachers. Temporary institutes for teacher education were all abolished in 1973. The number of institutes and the quota for pre-service science teacher programs in school year 2000 are shown in table 1. Approximately 2000 pre-service science teachers are produced every year.

Table 1. The number of institutes and the quota for pre-service science teacher programs (Data from Jung, 2000a)

	College of education	Education course	Graduate school of education
Public	11	16	20
	(725)	(272)	(3,782*)
Private	5	40	51
	(360)	(473)	(12,049*)
Total	16	56	71
	(1,085)	(745)	(15,831*)

* This is the quota for all subjects including science. The Quota for science teachers is flexible and amounts to about 10% of the quota.

Curriculum

In order to graduate from university, students should get 130 to 150 credits, of which liberal arts are 20%, the major field 60%, and elective 20%, respectively. In most colleges of education, the major field includes general pedagogy, science education, and science contents. The subjects and number of credits are up to universities. In the case of education course, the Education Law sets the minimum number of credits: 14 credits for general pedagogy, 4 credits for science education, and 2 credits for practice teaching. In graduate school of education, besides minimum 24 credits for a master's degree, the same number of credits as education course is needed additionally in order to get a teaching certificate.

Most pre-service teacher programs focus on science content area. The syllabuses and teaching methods are the same as those in college of natural science. Only two or three subjects, for example, 'theories of science education' and 'materials and methods in teaching of science', can be found in science education area. 'Introduction to education', 'educational psychology', 'history of educational thoughts', 'educational sociology', 'curriculum', 'educational administration', 'educational assessments', and 'educational technology' can be enlisted as subjects for general pedagogy. In addition to this, full-time practice teaching is held for 4 to 8 weeks in secondary schools.

Qualification and Certificate

All applicants for college of education take not only scholastic achievement test but also aptitude test and humaneness test. Students who enroll in education courses should be in top 30% of each department. National colleges of education provide scholarships for 40% of their students in order to induce excellent students. All students who have finished the courses established by the Education Law are given the 2nd level teacher certificate without taking any test.

Selection

Public schools

Since 1991, the metropolitan and provincial offices of education have held an open competition test every year in order to select and employ science teachers for public schools. The employment test for public schools is composed of the 1st test on

general pedagogy (30%) and the major field (70%) and the 2nd test of an essay test and interview. Table 2 shows details of the employment test for public schools science teachers. Also, numbers of pre-service science teachers applied and selected for public school in 2000 school year are shown in table 3. The competition rate is around 20% every year.

Table 2. Details of the employment test for public school science teachers

Section	Test area	Allot-ment	Problem type
General pedagogy	Introduction to Education, Educational Philosophy, History of Education, Educational Psychology, Curriculum, Educational method and technology, Educational Sociology, Educational administration, Law of Education, Educational Research, Assessment, Educational Statistics, Current Educational Policies	30%	Multiple choice (60 items)
Major	Theories of science education, materials and methods in teaching of science: 20-30% Major science: 30-20% Physics, chemistry, biology, earth science: 50%	70%	Short-answer, Extended-response
Essay	Composition about educational issues given	20-25%	Essay
Interview	Aptitude, views on education, personality, specialty, etc. as a teacher	5-25%	
Instructional ability	Preparing and implementing teaching plan, preparing CAI materials	10-20%	
Additional points	Graduated from college of education, residence, multiple major, minor, and computer skill related certificate holder		

Table 3. Number of pre-service science teachers applied and selected for public schools (Data from Jung, 2000b)

Subjects	Applied			Selected		
	COE	Non-COE	Total	COE	Non-COE	Total
Physics	581	505	1,086	154	37	191
Chemistry	695	782	1,477	128	50	178
Biology	808	852	1,660	104	36	140
Earth Science	390	146	536	89	12	101
Total	2,474	2,285	4,759	475	135	610

Private schools

In the case of private schools, there is no open competition test. The institutes select science teachers for themselves based on their needs. Numbers of science teachers who were employed in private schools in 1999 school year are shown in table 4. As you can see, the numbers of newly employed science teachers in private schools are smaller than those in public.

Table 4. Numbers of science teachers newly employed in private schools during 1999 school year (Data from Jung, 2000b)

Subjects	Middle school	High school	Total
Physics	26	25	51
Chemistry	18	33	51
Biology	24	37	61
Earth Science	5	10	15
Total	73	105	178

In-service training

There are 4 categories of in-service training for science teachers: Training for certificates; general training; graduate school; and overseas training. In order to get the 1st level teacher certificate, science teachers must attend intensive 30-day (180 hours) training course during the vacation after more than 5-year teaching experience. General training is for keeping up with the recent trends in education and science.

Especially, science teachers are required to take 60 hours of training every 5 years. Its main purpose is to understand the principles related to the experiments in secondary science textbooks through hands-on experiences and in-depth discussions with other teachers. Graduate schools of education provide in-service science teachers with professional knowledge about science and pedagogy. They award master's degrees after completing the part time program through nighttime courses or while-vacation courses. As for overseas training, science teachers can develop a comparative perception of education and science through visiting other countries' educational institutes for 10 to 12 days. Also, they are presented with an opportunity to obtain advanced teaching methods and scientific technologies in foreign training institutes for 8 weeks.

Reforming efforts in teacher education

Comprehensive evaluation of pre-service teacher programs

Problems and purpose

Improving teachers' quality is said to be a prerequisite for enhancing quality in education. For now, there are several problems in pre-service teacher education institutes. Specifically, it is difficult to differentiate their curricula from those in college of science. Also, pre-service teacher education institutes are not supported financially enough to update their equipments, and the number of professors who specialized in science education does not meet their demands.

Therefore, for satisfying various conditions and standards in producing well-qualified teachers as well as for upgrading teachers' abilities, pre-service teacher programs have been evaluated comprehensively since 1998. According to the result of evaluation, administrative and financial supports will be given to institutes with higher evaluation points. However, the institutes with lower evaluation points will be enforced to stop providing pre-service teacher programs.

Evaluation area

Seven main areas and points allotted for evaluation are shown in Table 5.

Table 5. Areas and points for the comprehensive evaluation

Main Area	Sub area	Points
Curriculum	Goal-setting in college of education; organization and operation of curriculum; and improving efforts of curriculum and its results	250
Instruction	Status of instruction; and full-time practice teaching	200
Professors	Employment of faculty; educational activities; research activities; and participation in in-service teacher training and community activities	245
Students	Efforts to select students; efforts to support students; and students' activities and achievement	100
Management	Administrative management; financial management; and supportive facilities management	200
Specialization	Background and goals for specialty; and strategies for specialty	30
Comprehensive evaluation from a qualitative viewpoint		30

Employment test for public school teachers

Problems and purpose

Employment test for public school teachers has been implemented since 1991 to select teachers required for the next year by each Provincial Office of Education. However, the validity and reliability of the test for the purpose of evaluating the quality of teachers have been criticized. Fist of all, in general pedagogy, most problems depended upon rote memorization and the number of test items was insufficient for covering its broad area. Also, in major subjects, the test items were produced by superintendents in Provincial Office of Education rather than by specialists, so the difficulty level of items were problematic. Consequently, improving efforts for selecting the qualified teachers led to change in tester, type and number of test items, and evaluation areas.

Changes in tester

Professors in specialty areas rather than superintendents in Provincial Office of Education have been in charge of paper-and-pencil tests since 1994. The new test items have required the test taker's deep understanding on subject areas as well as connection between them. Not only those, the test items show both recent theories on

science education and current issues and trends.

Changes in type and number of test items

Type of test items in major subjects has changed from multiple-choice to short-answer or extended-response since 1997. It can assess various reasoning abilities and inquiry process in science rather than fractional knowledge. In the case of general pedagogy, even though the test still maintains multiple-choice type, the number of items increased from 30 to 60 in 1998. Such a change made it possible to increase the reliability of test.

Changes in evaluation area

In spite of the changes above, paper-and-pencil test was not valid enough to measure pre-service science teachers' qualification. Even in the 2nd test, interview didn't carry much weight and what is worse, it didn't assess science teacher's actual teaching ability. As a solution to these problems, its evaluation area has been expanded to measure instructional ability since 1998. This test measures actual instructional ability based on teaching plan and/or multi-media operating skill depending upon provincial Provincial Office of Education. The actual instructional ability test measures pre-service teachers' ability to make impromptu teaching plan and/or to implement teaching plan given or of their own. The multi-media operating skill test measures pre-service teachers' ability to operate various multi-media and to prepare teaching materials using word processor and presentation software. These changes get acclaimed from pre-service teachers in that they should prepare authentic instructional ability instead of fragmentary knowledge.

Results of implementation

Changing curriculum for pre-service teachers

These reform efforts have influenced on the curriculum for pre-service science teachers. Above all, identity of pre-service teacher program has been consolidated. Second, besides pre-existing courses like 'theories of science education' and 'materials and methods in teaching of science', several courses such as 'computer and science education', 'secondary science experiment', 'teaching inquiry lab', 'preparing

teaching materials', 'media in science education', 'teaching experiment for inquiry', 'history and philosophy of science education', 'literature review on science education', and etc., have been offered. Third, professors who are in charge of teacher education have connected their science courses with secondary school science contents in terms of practical viewpoints. Finally, in-service secondary teachers have come to contribute to pre-service teacher programs.

Integrating programs into school of science education

Some institutes with poor qualification have been converted into colleges of science based on their self-judgment. On the other hand, most of the other institutes (10 out of 16 colleges of education) have integrated programs from discrete majors, for example, department of physics education, department of chemistry education, etc., into school of science education. Consequently, professors from each major field have shared the teaching load and educational facilities. In addition, students have come to understand science better through broader freedom of choice in their major or minor fields.

Supporting equipment and facilities

Pre-service teachers can have used new facilities funded by university administration in order to practice teaching methodology. They have utilized camcorder and VCR to come up with improved teaching techniques through analysis of skilled teachers' instructions or their own rehearsals. Furthermore, they have prepared instructional materials using multi-media and practiced technology-based teaching methodology in computer-equipped and internet-connected classroom.

Connecting with secondary schools

Various programs have been developed to reinforce the relationship with secondary schools. Some institutes have opened Internet Schools (for instance, http://uniweb.unitel.co.kr:8083 and http://science.kongju.ac.kr) for secondary students who want to get an access to valuable learning materials and to interact with pre-service teachers through the Q&A board. Also, Learning Centers for Science Prodigies have been operated in most institutes.

Conclusion and suggestions

The purpose of reforming teacher education in Korea is to foster and employ well-qualified teachers. The last teacher education policy of government focused on the quantitative control of demand and supply but the recent trend is how qualified teachers can be supplied. Such a change brought about the appearance of comprehensive evaluation of pre-service teacher programs and the reinforcement of employment test for public school teachers. These reforms make several positive changes in pre-service science teacher education.

Still, there are several problems to be dealt with regarding reform in teacher education. Above all, new consensus on what are the desirable qualifications for science teachers should be reached. The criterion for well-qualification has changed: The previous criterion was science teachers armed with science contents and general pedagogy, however, the present one is those equipped with practical teaching skills based on understanding current theory of science education and using hi-tech (OECD, 1996). So it is necessary for educational researchers to develop the new criterion to reflect on societal consensus about education and on researches about science teachers' qualification.

Second, government should provide autonomy and fair competition for teacher education institutes. In order to do this, government should relax administrative restrictions, make a continuous effort to improve the validity and reliability not only of employment test but also of comprehensive evaluation, and provide financially enough support for the institutes according to the results of comprehensive evaluation.

Finally, teachers have to raise their voice for reform in science teacher education. Even if teachers take an important part in education, they have seldom participated in reforming process. There are limitations in reform led by policy makers or professors regardless of teachers. So, science teachers who have a full awareness of problems in education should lead the reform in teacher education.

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Fostering Change in Science Education:

The Israeli Experience

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Abstract

During the 1960's and 70's, many reforms took place in pre-university science education around the world. Many of these were influenced by the pioneering efforts of the so-called α-β projects in the US (PSSC, BSCS, HPP, etc.) or the Nuffield projects in the UK. 35 years later, we find ourselves in the midst of a new wave of science education reforms all around the world. This renewed demand for change reflects, at least in part, dissatisfaction with the outcomes of previous efforts. The important projects of the 60's and 70's involved contributions from first rate subject matter experts. Most of these projects ended, leaving a large body of high quality learning materials available. Why, then, is there a need for a new cycle of activities? In trying to understand this dilemma, we find that there are a number of distinct modes of operation, which can be identified within the Science Education community. These will be reviewed in terms of their effectiveness and impact on the educational scene. In particular, the issues of continuity, implementation - in its broadest sense, and the role of educational research, will be discussed. This analysis will lead to a model, which needs to be adopted, in our view, in order to foster meaningful change in science education. We shall describe the Israeli experience, as an example where such a model has been adopted with some degree of success. We regard curriculum development as a continuous, **long term** process, consisting of four interactive components: *Creation* of the learning materials, learning and teaching strategies, their *Implementation* in the schools, *Evaluation* of the different stages of creation and implementation, which leads to better creation and implementation, and *Research,* which focuses on student and teacher needs, abilities and knowledge acquisition processes, examines the curriculum and teaching strategies, and is used as a basis for planning and refining the other components. These

components occur in interlocking cycles, and feed each other continuously. We shall describe some examples of this approach, where research based curriculum development, combined with intensive implementation, has brought about much improved instruction and learning of science topics. Turning our attention to future trends, we shall mention the work of a National Commission appointed by the Israeli Ministry of Education (1990-1992). This commission puts forward some basic premises, stating that *"knowledge of science and technology is the most important economic asset"* for any country. It stated further that *"mathematics, science and technology, are part of the general education required of every contributing member of society."* Following the adoption of this commission's recommendations by the Israeli government, a large number of science education projects were launched in Israel, under a five-year national program. We shall discuss some of these recommendations, and briefly describe some of the projects they triggered.

Foreword

The issue of how to foster change in the science education scenery is a very complex one. There are no clear truths and recipes, and as so often happens in the social sciences, to almost every argument there exists a counter argument that sounds just as good. However, the questions and dilemmas are very real. So when one decides to look at science education developments and reforms, one must submit to thinking within a context which is, at least partially, a social science context. This can be very different from what some of us, coming from the "hard" sciences, are used to doing in their own fields of research. This is being stated here by way of explanation. As Alan Schoenfeld has recently pointed out in relation to research in mathematics education [1]: "Findings are rarely definitive; they are usually suggestive. Evidence is not on the order of proof, but is cumulative, moving towards conclusions that can be considered to be beyond a reasonable doubt." What will follow, then, will not be anything resembling a scientific research paper, relying on hard experimental data, supporting statistics or even any thorough theoretical analysis. Rather, this will basically be a position paper, reflecting some personal beliefs, which slowly evolved from our experiences while working in this field in Israel, as well as watching and studying developments all around the world.

During the 1960's and 70's, many reforms took place in pre-university science education around the world. Many of these were influenced by the pioneering efforts of the so-called α-β projects [2] in the US (α-β stands for the acronyms these projects were given at birth: PSSC, HPP, BSCS, SMSG, SCIS, ESS, etc.) or the Nuffield projects in the UK. 35 or so years later, we are witnessing a new wave of science education reforms all around the world. Many countries are joining in and awakening to the need to upgrade their science education efforts.

That this is happening should come as no surprise: we are in the midst of a revolution, which is of no lesser significance than the industrial revolution of the 19th century. The last quarter of the 20th century will probably enter history as the era of the **sciences, computing, communication and information technologies.**

Human knowledge and capabilities are becoming the most important assets in determining the economic, political and even physical well being of any country. Within the wide spectrum of human knowledge and skills, the importance of mathematics, the natural sciences and related technologies is clearly increasing. Just compare the economic status of Japan to that of Saudi Arabia, and you have a direct realization of the relative importance of human knowledge and skills in science and technology, versus the availability of natural resources. This is not the topic of the present paper, but it ties closely to what we are dealing with here. The higher the level of **scientific literacy and competence** of the population of a country, the better off this population can expect to be in most respects. No wonder, then, that many countries are giving their science education scene a hard look, and are trying to improve it.

Curriculum Reforms: A Critical Look

Past Curriculum Reforms

Changes and innovations in the educational set up, in particular at a national level, are not a trivial exercise. It therefore makes very good sense to look at past experiences, to try to learn from successes and failures and to analyze what worked and what did not work, and in both cases - why.

We have already mentioned the surge of activities of curriculum innovations in the sciences, which started in the 1960's, and continued well into the 1970's. A

historical side remark is in place here: these activities are usually tied in people's minds to the SPUTNIK event: suddenly the US realized that the Soviet Union was ahead, and that led to an effort to upgrade science education in the US and then throughout the Western world. Just to put the record straight: PSSC was initiated in 1956, before SPUTNIK was ever heard of. An important influence which led to the way these efforts were structured can be traced back to the way science was done following world war II; to the methodology of teams linking together and working on large scale projects, rather than individual scientists working by themselves. This mode developed during the efforts of World War II and led to the establishment of national laboratories and large teams. It was natural for scientists, who became involved in curriculum innovation, to adopt a similar approach also in that effort. However, not to belittle the effect that SPUTNIK did have, we hasten to add that it is of course true, that once SPUTNIK was launched, the Americans got nervous, and the National Science Foundation in the US and other funding agencies started pouring money into science education.

We mention here again some of these projects [2]: **PSSC** in Physics, **H**arvard **P**roject **P**hysics, which in some sense was an ideological reaction to PSSC, **BSCS** in biology, **CBA** and then **ChemStudy** in Chemistry, projects aimed at younger age groups such as **SCIS and ESS**, all in the US, the very important **Nuffield** Projects in the UK, other projects in Europe - some in Germany, some efforts in Denmark, work done in the Netherlands, and others. Most of these were very good projects in terms of the learning materials that were created and published, being carried out by excellent people.

It is important to point out, that in most cases, the initiatives did not come from the field. The originators of these large-scale efforts were usually not teachers or people from government educational establishments. People who came from the academic environment, mainly universities, generally led them. This is an important point, to which we shall return later. An exception which should be noted were the Nuffield projects in the UK, where the initiatives came from some outstanding teachers, and they were the ones to get the academic community interested. A single exception, however, only serves to prove the general rule.

Let us remember how things were usually done: there would be a fairly large grant from some funding agency. Teams of experts: scientists, experienced teachers,

perhaps some media experts, technical staff, were assembled. Materials were created: textbooks, teacher guides, films, laboratory equipment for practical work, etc. Teacher workshops were organized, and the materials were tried out in pilot schools. As often happens, these first runs were generally quite successful, and also served as the first round for feedback. There is the well-known Hawthorne effect. A large body of literature suggests that if people feel that changes are made in their own best interest, they will do better and work harder, regardless of what the changes actually are. However, the effects of these changes often fade with time. So there was the enthusiasm and freshness of innovation: the teachers who participated in the first trial runs were those who were keen, open to innovation and anxious to succeed. But after perhaps another cycle of trial runs - feedback - corrections, the grant would run out. The materials would be published commercially, and the teams much reduced or even dismantled. The scientists would then return to their research laboratories, the feeling being something like: *we have put the train on the right track, now let it roll...* So now there were innovative materials available, and there were pockets here and there of teachers who were familiar with them.

This is one mode of operation, which was very typical of the science curriculum reforms of the 60's and the 70's. For future reference, let us call it **Mode 1**.

The advantages of Mode 1 are obvious: there was input from the best subject matter experts, as well as contributions of enthusiastic teachers who were willing to make the intellectual effort and put in the work. Looking at the harvest of learning materials that these years produced, the effect was quite remarkable. They were very exciting, innovative materials, much superior to what was previously available.

What, then, if anything, went wrong?

Melba Phillips put it best when she said: ***"The trouble with problems in physics education is they don't stay solved."*** Indeed, this is true not only for physics, but for all other branches of science and mathematics as well.

Ken Wilson is the 1982 Nobel laureate in physics, and in recent years he dedicates much of his time to studying educational reform. He has coined a phrase to describe the syndrome, which most educational reforms suffer from: ***"Five years and Out".***

Five years, since the NSF or other funding agencies usually finance projects for no longer than that. Why the "Out"? Well, a host of problems can be identified here.

Implementation

One central issue is that of *implementation*. . The availability of good materials does not ensure good teaching or successful learning. First, school administrations need to get used to a host of new needs and demands which modern science teaching presents. Beyond that there is the problem of *continuity*. Inherently, the educational system is very conservative and slow to adapt to changes. Teachers tend to stick to their habits, and are not necessarily eager to make the effort, which such changes demand. The majority of teachers need to be trained and introduced to new materials and approaches. What is necessary, then, is an intensive effort of teacher training, pre-service for those in the pipeline, in-service for those already working in schools. Guidance in schools, and continuous encouragement, as well as help in the process of implementing the new materials and approaches, must be available in massive doses. However, short-term in-service training programs, usually initiated together with new curriculum developments, do not provide the appropriate settings for long-term professional development of teachers.

We shall return to this issue below, when we describe the Israeli efforts.

Continuity and Research

There are additional issues. Some scientists may dislike what we shall say here, because scientists are at times somewhat arrogant, thinking that their scientific expertise is all that is necessary to ensure "good" science education. However, during the development phase, many mistakes are made, and they are almost unavoidable. Scientists, who are subject matter experts, push for innovation, breadth and depth. These scientists are often not aware of the abilities and disabilities of their target population. When innovative learning materials are developed, they need to be tried out and their suitability assessed. Then they are usually corrected and changed, tried out again, corrected again, and so on. In other words: cycles of *development - implementation - assessment - feedback - correction and change - repeated implementation* - are necessary. It almost never happens that the first trial of a new piece of curriculum is such a success that no revisions are necessary, even if the

science included is all correct and exciting.

Let us amplify this point. It often turns out, that in spite of all the learning materials developed, excellent as they might seem to be, the goals are not achieved, and students understand very little of the science they have supposedly been taught. In recent years it is becoming obvious to researchers, that students' facility in memorizing facts and vocabulary, extends to memorizing algorithms and procedures. This phenomenon is not confined to the lower schools. Research shows that students at all age groups exercise some of the same rote talents in simulating understanding of science. It is becoming painfully clear, that very often we cannot assume that students have understood even some of the fundamentals. The picture becomes even gloomier when one looks at what some of the teachers themselves understand of the science they teach. So we find ourselves in a situation where very serious research on the teaching and learning of science is called for, in order to identify foci of difficulty, understand the sources of these difficulties, and look for ways to overcome them. Again, the outcomes of such research, if it is any good, will define new directions of development work, implementation, evaluation, etc.

A short-range project is not geared to accomplish all this. Without continuity and persistence, the chances for success are very low indeed. Using a physics-based metaphor, we know that when a physical system is excited, then left alone, it will normally decay back to its lowest state. This is true for educational system as well.

These were some of the drawbacks of Mode 1.

The surge of activities at various academic centers, more or less along the lines of Mode 1, as defined loosely above, gave birth to a new field of activity, which actually evolved into a scientific discipline: the discipline of *Science Education*. In 1950, say, such a discipline did not formally exist. Today, many academic institutions have departments of science education, or centers for science education, or any similar names, which such centers of activity carry. In most cases, such centers are part of a school of education (or faculty, or college, again depending on what the norm is at that particular institution). This is often a source of some problems. Unlike many other areas of human intellectual endeavor, science develops and changes very rapidly. Professors of Education, whose education in science is 20 or 40 years out of date, are not well equipped to train new science teachers, or to deal with some of the problems which were mentioned previously.

Secondly, these academic structures which we are talking about, are very often patterned along the usual schemes which govern university departments. Research for its own sake becomes the main activity. The sociology of academic institution, with graduate students, publications, promotion schemes, struggles for slots and tenure, and all the rest of what typifies our universities, all that takes over, in a sense. Within such centers, then, activities are often purely academic in character (after all, this is what a respectable university is about), but their *impact* on the educational system becomes minimal. We hasten to emphasize immediately, that this does not imply that educational research is superfluous. We have already emphasized how necessary such research is: it is what Mode 1 was so badly lacking in. However, we refer not to psychological research - which has had little impact on teaching in other disciplines - but research *indigenous to specific subject matter areas*, such as mathematics, or physics, or chemistry or biology. We suggest that in order to help the very difficult task of improving science education, such research needs to be *mission oriented*. Research which is not integrated into any development or implementation activity, or preferably both, can easily become sterile.

We have now identified what we believe to be *necessary ingredients* for successfully reforming science education:

- Continuity and persistence
- Scientific/subject matter expertise
- Applied research on teaching and learning

Practicalities - Models for Science Education Reform

From what we have described so far, the reader will easily identify what we believe to be an effective model to foster change in science education. What is needed is a combination of development, in which learning materials are created and teaching strategies are developed, and intensive implementation efforts. The implementation involves teacher courses, workshops, in-school guidance, and a whole range of related activities. The whole enterprise should be accompanied by on-going formative evaluation, and by a spectrum of research activities which feed the development and implementation efforts and help in overcoming problems encountered in their course.

Reform Efforts – Who and Where?

The discussion so far dealt with the principles involved. Now we need to look into some cardinal questions, concerning how this very general model can be activated in practice.

Here are some of the issues that come to mind:

Where will all this happen? Who will run these complex enterprises? Will it be done by Government institutes? By Ministries of education? By Publishers and producers of textbooks, software, equipment, etc.?

It is probably unwise to try to prescribe a single recipe here, but we have learned a few lessons during the past 35 years in Israel.

We have already noted that the innovations of the 60's and 70's originated from within the scientific-academic community. Our experience in Israel shows, that this is the preferred option, and we believe that this can probably be generalized. After all, the frontiers of science move very rapidly. In this context, we are reminded of a statement by Albert Abraham Michelson [3], the first American to win the Nobel Prize in Physics (in 1907), who said in 1894:

> "*The more important fundamental laws and facts of physical science have all been discovered, and these laws are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote . . .*
> *Our future discoveries must be looked for in the sixth place of decimals.*"

Do you appreciate the paradox?

It is the year 1894, and this is what Michelson, a world-renowned scientist, had to say about his own discipline of physics. The time - just before the turn of the 20th century, which brought with it the Theory of Relativity, Quantum Theory and Quantum Mechanics - all revolutions in human thought, followed by the enormous developments in science and technology which we saw during this century. Michelson himself won the 1907 Nobel Prize in physics for his important contributions and landmark experiments connected the theory of special relativity. So if Michelson could fall into such a trap, how careful must we all be!

This feature of rapid, unpredictable change and development dictates that science education must be on the alert, and be flexible enough to respond to the ever-

changing needs. There is a constant struggle to define what belongs into the school curriculum, what can be taught, what is important, and even more difficult - what can be left out, and what will best serve to prepare an enlightened, scientifically literate, citizen. To define such priorities, a good understanding of science, its developments and current trends, is essential. The only place where the necessary understanding, expertise and sensitivities exist, where knowledge is constantly being updated, are the academic environments, universities or perhaps various research institutes in the sciences. Note that we are not talking about departments or colleges of education, but rather about the science departments in such places.

Indeed, the initiation and development phases, as they existed in the Mode 1 type operations during the 60's and 70's, were of such nature: they were led by top scientists.

There may of course have been in the past, and there probably exist now, some local initiatives: an energetic teacher developing a module on this or that, or a team of teachers in a particular school working together on something interesting. It is quite common for large publishing houses in some countries to commission writers to produce texts for them (the US is one example where this is very common). Often a long list of notables serves as an ornament on the title pages of such books, so that the consumers then believe they are getting quality materials. Such commercial enterprises are, of course, driven by the prospect of making a profit. Nothing wrong with that, in principle, except that commercial and educational considerations do not necessarily overlap.

By and large, we believe that the teams in an academic, science centered environment, will do a superior job, since they will not be doing it for a profit, but rather regard it as an academic enterprise, worthy of their talent, dedication and effort.

Implementation and the Educational Systems - Centralized or decentralized?

Next comes the issue of *implementation*. Put simply: how do we get the materials into the schools and how do we ensure they are being properly used? Implementation involves a complex array of activities, which we have already talked about previously when we mentioned what Mode 1 did not have enough of. It involves a very close interaction with the school system, the administration, the inspectors, the testing authorities and many other bodies.

In trying to think about how this necessary cooperation can best be achieved, we realize that school systems in different countries are organized very differently. Specifically, one important aspect is: how centralized is the educational system? The instinctive reaction of most of us, regarding this issue, would probably be to prefer to have the system as decentralized as possible: the less interference from above, the better. Governments have this tendency to become overbearing and to choke creativity with bureaucracy. People function best when their originality is allowed to blossom, and we would expect this to be true of our teachers too. One could go on arguing for maximum decentralization. An extreme example of this approach is the US: practically no national standards used to be enforced, and until quite recently, none even existed. At most, there were some State requirements. The responsibility usually rests with the local school boards, which are elected bodies. How beautifully enlightened! Only why is it, then, that so many Americans are so deeply dissatisfied with the education their children receive?

We can quote from the well-known report published in 1983 [4], and there have been others, of similar character, since then. In that particular report we read:

> *"If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves."*

Strong words indeed...

Another example can be found in the English system. Teachers and schools were traditionally given a high degree of autonomy. A lot of dissatisfaction with the system has been expressed there in recent years.

So democracy and "laissez faire" and all this enlightenment is fine, but how do we guard against mediocrity or even anarchy?

The difficulties can be traced, at least partially, to the niveau of our teachers. If the teaching profession were to receive the best and most able, then perhaps it could all be left to them. We do not know of many countries where teachers are the sector commanding the highest salaries, or the prestige and respect that some other professions have. That being the case, teachers are not necessarily the cream of the

crop. This is stated here with strong reservations, knowing that it does injustice to many dedicated, able and creative individuals. But in gross generality, it represents a sad reality. It certainly is the case in Israel. Stated very simply, teachers need to be directed and helped with the difficult tasks of choosing which directions to take, what to teach, and how.

These concerns, of inadequate educational standards, led to the reexamination of goals in many countries, and frameworks are being devised to establish a common base and to set standards in the learning of science. Examples that come to mind are Project 2061 in the US [5], the National Science Education Standards in the US [6], and the National Curriculum in the UK (1988).

Put differently, even some traditionally decentralized systems are moving towards some degree of centralization, in order to ensure an adequate level of scientific education.

Other countries have always had national graduation requirements, which are enforced through centralized examination systems. This is common in many of the West European countries (France, Belgium, Germany, Italy, and others), and it is also the situation in Israel.

From the viewpoint of implementation, a centralized system has clear advantages. Access to large portions of the system, and reasonable levels of implementation can be reached, if there is the support of the authorities. What it does require, is a close collaboration of the innovators and developers with the authorities in charge of the schools. That is sometimes easier stated than achieved. Once government bureaucrats, appointed inspectors and other officials have the authority, they want to be in control. Such is human nature. Now it becomes a question of chance, perhaps some diplomacy, or both: an enlightened inspector, who understands an innovative curriculum, agrees with its goals and approaches and wants it implemented, will be a great asset to the whole process. In contrast, nothing can be more obstructive than an inspector or school principal, who for whatever reasons does not want to see innovations and changes implemented.

So you see how from academic principles we have suddenly come to consider political issues. That, however, is what real life is like. We are dealing with complex systems, in which many parameters come into play.

The Israeli Science Teaching Center

The Israeli Science Teaching Center was established in the mid-60's, as a cooperation between academic institutions (at first two, later others joined in), and the Israeli Ministry of Education. As already mentioned, the original initiatives came from academia. More specifically, as is so often the case, a few concerned individuals, who saw it as their duty to influence Science and Mathematics education in their country, plunged in and started the activities.

In the beginning, what basically evolved, was a Mode 1 type of operation. These beginnings were somewhat naive, since in those days there were no well-defined procedures of curriculum development or much experience about. Things were done intuitively, but the operation had the correct principles incorporated into it from the start. Teams were assembled, consisting of scientists as leaders and initiators, but they included active teachers from the various disciplines as the main body of executors. One cannot over emphasize the importance of this combination. We have already previously stated our belief, that scientists alone could not do the job. Teachers, on the other hand, needed the driving and the environment, as well as the subject matter expertise, which such a framework offered.

Support in terms of budgets, as well as the cooperation of the people in charge - school principals, inspectors, etc. - was assured by the involvement of the Ministry of Education. So from the beginning we were fortunate to have established a structure which had most of the necessary ingredients built into it.

Compared to most initiatives mentioned before, there was a very important difference: the operation was not abandoned after one or two cycles of curriculum were produced. In fact, it was never stopped at all. Today, over 35 years later, the Israeli Science Teaching Center is larger and much more active than it was in its first years.

The beginnings, then, were intuitive. There was a surge of production of new learning materials, teacher training activities, and other implementation efforts. However, as the first cycle of materials which had been produced came into place and started being used, there came the phase of serious *evaluation* work, which in turn triggered intense *research* efforts, which in their turn defined new directions of

necessary *development*. This is a very general description. There are enormous variations, depending on the age groups towards which a particular effort is targeted, the preparedness of the teacher population, the subject matter area, and many more parameters. A basic general science course for the 13-year-old presents different challenges and questions than an advanced unit on astrophysics for high school students, say. Still, some principles are common to all such projects.

The discussion so far may have left you with a conceptually erroneous picture. We have used the terms: *creation - implementation - evaluation - research* in that order, and it may have sounded as if these activities occur in tandem, one after the other. That is probably how it happened during our first trials, back in the 1960's and 70's. However, as our approach matured, these components became more and more mixed, and they occur in interlocking cycles, feeding each other continuously. So a better representation would be a sort of spiral, as depicted the following figure:

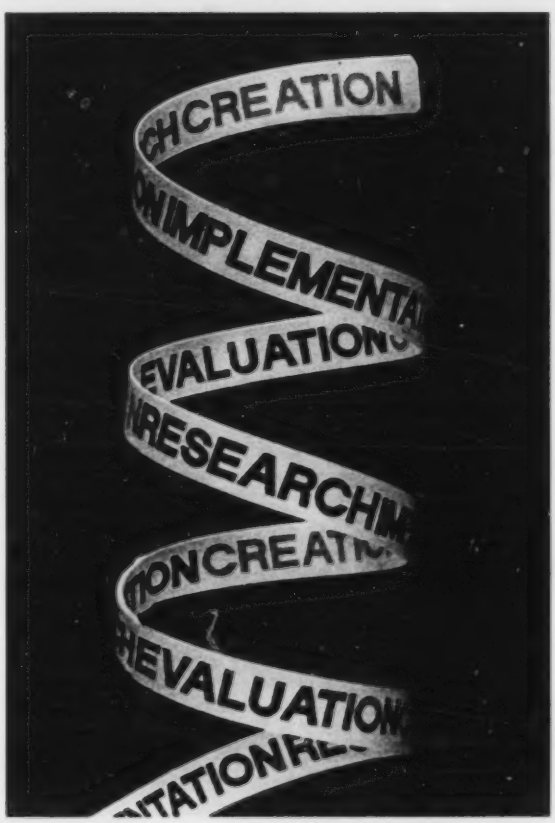

Figure 1

We should probably translate these generalities into specifics, by describing what was actually done in some typical projects. This cannot be done in proper detail within a limited frame such as the present one. We shall, therefore, give only some outlines regarding one or two projects, which operate in our Department at the Weizmann Institute of Science, to exemplify how things are done.

Research Based Curriculum Development-Some Examples

The High School (HS) Chemistry curriculum in Israel has been one area of continuous activity. In the mid-1960's, the first efforts concentrated on translation and adaptation of the ChemStudy program, which originated in the US. The approach adopted was reflected in the name of the course *"Chemistry - an Experimental Science"*. However, our educational system is very different from the one in the US, and so this course was unsuitable in many respects. This taught our chemists a valuable lesson: adaptation of a course from a different country, different culture and different educational system, is generally not a very useful path to follow. Certainly it makes good sense to learn from our colleagues in other countries, and it would be foolish not to build on accumulated wisdom and expertise. Simple translation, however, is not the way to go.

The next generation, then, was developed from the beginning, building on the accumulated experience from the previous exercise. *"Chemistry for High School" was* the course, which most high school students, who chose to emphasize chemistry, went through during the 70's and early 80's.

Once the materials were available, the efforts shifted somewhat. The rate of development could be slowed down, and more attention and time could be devoted to cognitive research. An additional factor which came into play were the changes in the target population, from selective classes of science oriented students to heterogeneous classes including lower ability students. Diagnostic studies of students' learning difficulties in the various areas of the chemistry curriculum, led to a complete re-conceptualization of the curriculum [7], and this resulted in a new curriculum:*"Chemistry - a Challenge"*. This curriculum attempts to respond to students' learning difficulties in various domains. For example, it carefully responds to issues of memory load resulting from the need to integrate different levels of description in chemistry. The program is also very sensitive to the use of various

representations and the meanings that students attach to them.

As another example of a similar chain of events, let me describe the evolution of our *Electricity and Magnetism* (E&M) course, which is a central part of the Physics HS course in our country.

Again, going back to the early 1960's, the first edition of the PSSC physics course was translated into Hebrew by a private publisher. However, this is a one-year course, aimed at 16-17 years old students and geared towards the American system. Nonetheless, our physics group adopted many of the approaches and ideas PSSC initiated. We also learned a lot from the Nuffield (UK) materials and looked at many other curricula. Having absorbed all that foreign wisdom, we then started carefully developing our own HS physics course. It was planned for 3 or 4 years, starting at age 14 or so, as is common in many European educational systems. The 1970's were years of intensive development and implementation efforts, and physics teaching and learning in Israeli High Schools greatly improved during those years.

Again, changes in the target population, as mentioned above, necessitated some serious consideration of learning difficulties, which became manifest as the curriculum was being used in schools.

Cognitive studies aimed at identifying foci of difficulty in our 9th grade course, were followed by the development of special remedial materials, based on the diagnostic results of that study [8].

Once our awareness to the problems of younger students became acute, we realized that similar issues, concerning our older students, were also worth investigating.

One such study [9] concentrated on student understanding of some central concepts in electricity. Specifically, how students perceive and use the concepts of *current* and *potential difference*. The outcomes were revealing, since they substantiated some of our long-standing suspicions. Students often use certain concepts algorithmically without much understanding of the underlying physics. Still, they pass examinations successfully by developing formula manipulation techniques, which carry them through most of the standard tests. A detailed follow up study [10] enabled us to formulate some assumptions regarding the sources of student difficulties. In particular, we put forward the assumption, that in order to understand the phenomena that they observe at a *macroscopic* level, students must develop some

robust mental models for the *microscopic* processes that occur. The outcomes of this research have been applied in the development of a new course on E&M, and it is now being used in our high schools.

An interesting side remark: during this R&D effort, we have been in close contact with a group at Carnegie-Mellon University in the US. They have developed a new university course on the same topic [11], in which they have adopted similar principles to the ones that we adopted in Israel, following our research findings. In a recent study [12] we were able to compare the performance of students who had studied in a traditional E&M course to that of students who were taught with this new approach. The results clearly show that students who studied the new course developed a much better in-depth understanding of the topic.

These were two examples of R&D efforts, which combined development, on-going evaluation and research, not necessarily in that particular order. In both cases, our evaluation studies have shown that successive refinements of the curriculum on the basis of assessing conceptual knowledge, have culminated in programs which responded to many of the learning difficulties that have been identified previously in the relevant domain.

It should be emphasized that all these R&D activities reflect a cooperation of scientists, teachers and graduate students, whose research towards M.Sc. and Ph.D. degrees is concerned with topics which need investigation, while the development effort is going on.

Many other examples of similar activities could be given. The point that clearly stands out, we suggest, is that the best place for this complex array of activities to take place is within an academic environment. However, as already stated, professors of science (physics, or chemistry, or biology or any other scientific discipline) will not accomplish it all by themselves, and so it requires the full dedication of those who make it their profession.

Present and Future: On-Going Reform Efforts in Science Education

The "Tomorrow-98" report

Israel is similar to most developed countries in its dependence and reliance on science and technology, an issue already mentioned briefly above. So similar to most Western societies, we have had these periodical bursts of nervousness, when the

government, or some politicians, or both, took up the issue of science education and literacy and - like that shepherd in the story – started to cry: "Wolf". With the end of the millennium approaching - another favorite cliché - the Israeli Minister of Education appointed in November 1990 a distinguished commission, headed by Haim Harari, president of the Weizmann Institute of Science. The commission was given a broad mandate. It was asked" *...to examine the state of scientific and technological education in Israel."* It was further asked to *"...submit recommendations for new programs, changes and improvements in the education system, both educational and structural, and any other measure that will help scientific and technological education in Israel move into the twenty-first century."*

In August 92 a final report was submitted [13]. The Israeli government adopted the report and decided to activate the implementation of its recommendations. That meant that large budgets had to be allocated for this purpose.

The report did not elaborate on specific syllabi for school subjects, what needed to be taught, etc., but it pointed to the general directions that needed to be taken. It contained 43 specific recommendations, organized in four chapters:

1. Mathematics, Natural Sciences and Technology for Everyone.
2. Mathematics, Natural Sciences and Technology for students specializing in the Sciences.
3. The Computer as an instructional tool.
4. Organizational Structure.

Here are some excerpts from the report. Later we shall mention some activities we have taken up towards their implementation.

- *Knowledge of Science and Technology is the most important economic asset. The State of Israel should declare a National Program to strengthen, deepen and improve studies in mathematics, the natural sciences and technology...This program should be implemented over five years... Significant progress will be achieved by 1998, the jubilee anniversary of the state of Israel. Suggested name:* ***Tomorrow 98.***
- *Today, and even more so in the future, mathematics, science and technology are part of the general education required of every contributing member of society... A certain ability to think quantitatively and scientifically... understand and grasp*

a scientific or technological problem... understanding the basic rules of the language of mathematics, science and technology...are essential components in the training of every future citizen...Therefore, instruction in mathematics, science and technology should be expanded to include students in pre-school, elementary school and junior high school, as well as high school students in all tracks who do not receive a broad education in the sciences. (Note the emphasis on **every student**).

- *Science and Technology are interrelated and affect each other in a variety of unexpected ways. Mathematics and Science are the basis for all technological innovations. The boundaries between most sciences and related technologies are artificial and outdated ...Today, every technological occupation demands an interdisciplinary scientific background...*
- ***A discipline that incorporates both science and technology should be introduced in the junior high school on a wide scale...***

Courses in science and technology must be integrated in the curriculum of all students, including those who do not choose to enter a scientific track in high school.

- *Although technologies change quickly, their basic principles remain valid...*

It is pointless to deal with details of rapidly changing technologies in the classroom...

If it were done, a high school student would be specializing in technologies that will have disappeared by the time s/he joins the work force. The basic principles on which the technologies are based, however, remain constant... Teaching the basic principles becomes particularly crucial...

The report emphasized that **teachers are central to any innovation and reform effort**. Hence, a large variety of activities to help teachers were proposed:

- *wide range of in-service activities*
- *regional support and guidance centers*
- *training in utilization of computers for science/mathematics education*
- *technical assistance in the laboratories*
- *professional journals.*

- *A broad, **systems based approach** is required if improvements are to be made in teaching mathematics, science and technology. Good results depend on integration of curricula, texts, laboratory aids, computer courseware, well educated and appropriately trained teachers, well equipped laboratories, sufficient contact hours and a guidance and support system for teachers.*
- *Implementing the recommendations of this report will depend upon a high level decision and the creation of a special project administration in the Ministry of Education.*

The cost of operating the program was carefully estimated, based upon the assumption of full implementation of all its components.

The stage was thus set for launching a large-scale effort on a national scale. The Minister of Education at that time appointed a person to head the effort. However, in a heavy bureaucratic system like a Ministry of Education, the whole enterprise quickly became highly politicized, with the "old guard" being very nervous about their "latifundia". So the whole enterprise did not take off as an integral coordinated effort, as envisioned by the originators of the report. Still, once budgets were allocated for the operation, many projects were launched, designed to implement certain parts of the recommendations. Some of these projects, started around 1993, are still going on, and they have a great impact on the educational system.

Present and Future Activities

Since its inception in the mid-1960's, the Science Teaching Center at the Weizmann Institute of Science has been working in the content areas of

- *Mathematics, Physics and Chemistry* for Junior High School and Senior High School.

In later years, we have expanded this range to include also

- *Computer Science* for Senior High School.
- *Earth & Environmental* Sciences for all ages (K to 12).
- *Life Sciences* for Senior High School.

Within these content areas, we cover a broad spectrum of research and development activities:

- *Curriculum Development* includes: Textbooks, Teachers' Guides, Remedial

Materials, Educational Games, Computer Software, and Special Units of Assignments and Projects.

- *Implementation* activities are diverse and include continuous In-Service Teacher Training, In School Guidance, Young Teacher Fellowships, Journals and Newsletters.
- *Evaluation* and *Research* activities are diverse, and consist of various surveys, evaluation of materials and methods, and cognitive research.

Once the recommendations of the "Tomorrow-98" report were activated, our efforts in a number of these areas have greatly expanded. Some of the new areas of activity will be mentioned here briefly.

Science and Technology for All: In the past, the scope of science taught in Israeli Junior High Schools (ages 12-15) was quite limited. This was an unfortunate state of affairs, since it is well known that students in this age group are curious, their interests are shaped, and their attitudes towards science crystallize. Furthermore, while students who opted for the scientific track in high school received a fairly extensive exposure to their subjects of choice, the majority of students, not making such a choice, would come out of their schooling experience with a very poor understanding of science. The "Tomorrow-98" recommendations (quoted above) specifically addressed these issues, and so we decided to initiate a number of R&D projects to deal with them. Our aim here is to reach an acceptable level of science literacy for **all students**, in all tracks of the educational system.

A large scale R&D development project has been launched, in which a new school discipline is created, entitled *Science and Technology for Junior High School*, incorporating Science and Technology in an integrated approach. This topic will be taught to all junior high school students (grades 7-9). A detailed syllabus has been written, in which we emphasize an integrated approach: Physics, Chemistry, Biology, Earth Sciences and the related technologies are all combined and presented in a coherent fashion. For example, when a topic in biology is discussed, the necessary chemistry background has already been studied, and the physics needed for that has been dealt with before. Thus, the sequencing had to be planned very carefully. Furthermore, because of the interdisciplinary nature that is involved, most teachers cannot be expected to be able to teach the whole subject by themselves. Schemes for

cooperation and team teaching have to be developed. This involves both an extensive curriculum development effort of new learning materials, as well as a wide range of in-service training of the teachers who will use them.

A second project aims at Senior High School students (grades 10-12), who do not specialize in any of the sciences. Again, a new school subject is being introduced, called *Science and Technology in Society*. It adopts an STS (Science-Technology-Society) approach [14], and is made up of modules, each dealing with an issue from a number of points of view: the science, the technology associated with it, and the societal issues involved. A qualitative approach is taken as far as possible, without sacrificing the accuracy of the information presented. Some examples of such modules are: *Energy and the Human Being; The Black Gold* (About Petroleum); *Brain and Drugs; From Dinosaurs to Darwin* (Evolution in Time); *Science: an Ever-Developing Entity*. Again, both development of new curriculum materials, and an intensive effort of in-service teacher training are necessary, for similar reasons as those alluded to above.

National Teacher Centers: As we have previously emphasized, a necessary component of any curriculum innovation enterprise has to be a serious teacher training effort. Pre-service programs run by departments of education in Israel are aimed at providing teachers with general educational background, as well as acquaintance with the didactics of their specific discipline. In the past, our in-service programs were organized to train teachers how to teach a certain new piece of curriculum, learn a new curricular approach or to master new skills (for example-the use of instructional technologies). Accordingly, most of our in-service programs in the past were short-term workshops (3-10 days) run during school vacations, in which teachers were introduced to specific topics or methods. While we clearly understood that this mode of operation was insufficient, we were usually limited by budgetary constraints. Short-term programs do not provide the appropriate settings for long-term professional development of teachers. They are definitely insufficient to induce meaningful changes in teachers' ideas, perceptions and behavior. Indeed, we found that when the teaching methods presented in these programs were congruent with previous experiences of the teachers, they would usually adopt them. When the approaches were different from existing practices, teachers would usually

adopt very limited aspects of the new approaches, or change them to fit their existing practice. In order to allow the necessary learning and adaptation by teachers to take place, it is essential to allow more time, and take a different approach to the training process, one that allows the teachers to gradually change conceptions and eventually their practice. Pre- and in-service programs must be regarded as a continuum of life-long professional development. Accordingly, we are changing our conception of in-service programs, and taking a wider view of promoting professional development through long-term in-service programs.

The "Tomorrow-98" report recommended (see above) to create **regional teacher centers** all over the country, in which professional development will take place continuously. As a first step towards realizing this recommendation, **National Teacher Centers** were established for the various domains of science and mathematics. These centers are designed to support the activities and development of teachers throughout the country. One of the central activities of these centers is to prepare the educational leadership and support its activities in the regional centers, adopting a "fan model" (figure 2).

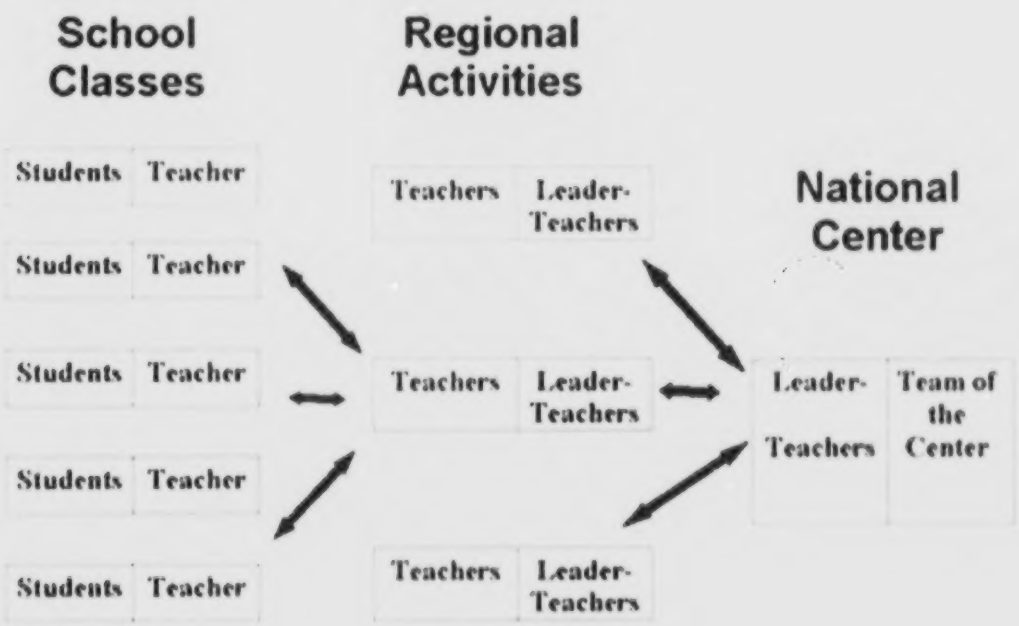

Figure 2

The leader-teachers go through an intensive training procedure, consisting of a profound elucidation of their educational-didactic work, of enriching their subject-matter knowledge, and of developing their guiding skills. Typically, the courses we run for leader-teachers extend over three academic years, during which they spend one day a week at the National Center. The program is designed on the basis of several principles: (1) Participating teachers need to develop professionally as teachers. (2) They need to develop professionally as leaders. (3) The program is designed to help the leader-teachers choose and/or design models for programs they will run at the regional centers and provide a framework for the initial preparation of tools necessary for running them. This elect group then undertakes a variety of regional activities, such as training teachers in regional centers or in schools, and providing guidance to both teams and individual teachers. In the years that follow, they themselves initiate training and guidance activities in the regional centers, utilizing materials and experiences that they had acquired and developed during their three years of training. The regional training activities are supervised and supported by the team of the national center throughout the year. This close interaction includes workshops for the "Graduate Forums" (the leader-teachers who run the regional activities), designing and preparing materials and meetings, counseling, and coordinating the regional activities by means of conferences, in which the teachers who participate in the professional training activities take part. The level of support decreases with time, as the leader-teachers gain experience and confidence, and become more independent.

Finally, we mention briefly some of the issues we have been concerned with in recent years. Most of these should be familiar to any science educator, as they are not unique to our - or any other - educational system.

Contemporary Science in the curriculum: there is a continuous struggle to keep up with the rapid developments of science. This can cause the curriculum to blow up beyond control. Judicious decisions become necessary, in particular - deciding what can be left out, since the time frame for school science remains approximately the same in spite of all these developments. For example, dealing with our high school physics curriculum, we had to overcome a lot of resistance before we were able to modernize the curriculum. As we used to argue repeatedly in our discussions with the

inspector - *we should teach 20th Century Physics to our High School students before the end of the 20th century...*

Educational Technology:

What are useful modes of utilization of the new technologies? How to change the didactics in view of the availability of these new means?
Networking and using the World Wide Web efficiently - when and how?

Teaching for Understanding:

The problem of depth versus breadth ("less is more").

Promoting scientific reasoning.

Changing the traditional classroom modes of teaching, developing independent learners, and the changing role of the teacher in this process: in our science classrooms, we try to evolve away from the situation depicted in the following figure, since we know from good evidence that lectures are not very effective, leaving the student almost totally passive most of the time.

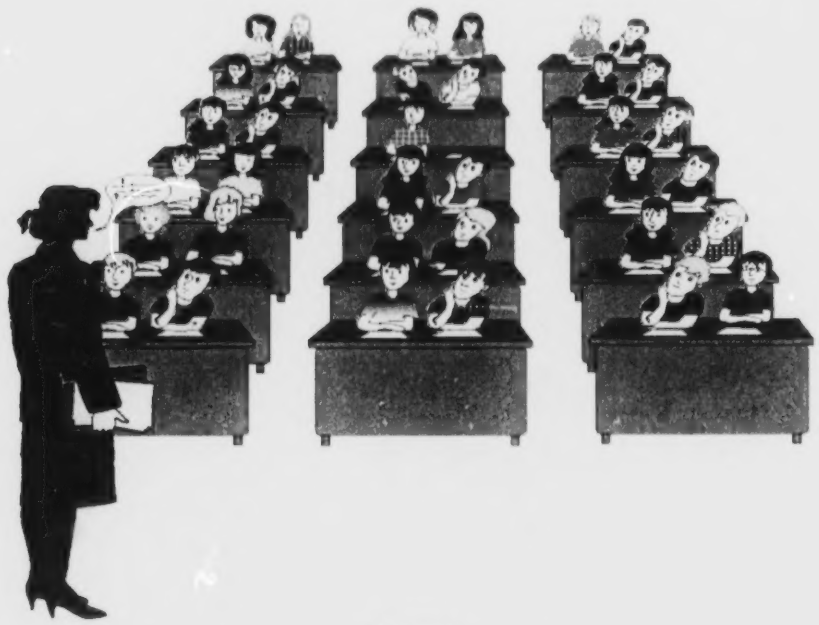

Figure 3

Indeed, it has been stated that *the lecture method is that process by which the contents of the instructor's notebook are transferred to the student's notebook without passing through the mind of either...*

A somewhat similar sentiment is expressed in the introduction to the US National Standards [5]: *Learning Science is something that students do, not something that is done to them.*

That means that it is necessary to structure the teaching-learning environment in appropriate and often different manners. A lot of research and effort are needed to devise various modes of instruction and develop the appropriate learning materials, so as to achieve these goals.

Conclusion

In concluding, let me emphasize again: innovation is a slow process, and it requires time. To foster innovation, a systems approach is needed, in which longitudinal, progressive refinements of program development, school and classroom organization, teacher training, assessment and cognitive research, are all considered and activated together. Being slow, innovation takes a long time. There are no quick fixes; hence patience and persistence are of the essence.

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Session III.

US Redesign in Action, Lessons Learned along the Way, and Assessment Efforts

Designing a Major for Prospective Middle School Math and Science Teachers

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Recently, the State of Ohio completed a major revision of the licensure requirements for K-12 teachers. This has prompted the Ohio State University to review its teacher preparation programs, and has offered the opportunity to reconsider all aspects of teacher preparation. The College of Mathematical and Physical Sciences has been working closely with the Colleges of Biological Sciences and Education to establish a major specifically designed for Middle Childhood (4-9 grades) Math and Science teachers. The following is a description and rationale of the program.

Teacher preparation reconsidered

From the state legislature to the school systems, University administration and the colleges of Arts and sciences and Education, as well as nationwide studies and councils, there are many sectors calling for serious reconsideration of teacher preparation programs.[1,2]

This reconsideration of teacher preparation can be distilled down to one core question: **How do we prepare teachers to maximize student achievement?**

This deceptively simple question has several secondary questions that must also be answered:

- How is student achievement defined and measured?
- How do we know which aspects of teacher preparation are important?
- What kind of support should the program give to post-graduates to ensure both maximum induction into the teaching profession and optimal student

achievement?

- How does an effective teacher preparation program fit within the structure and environment of the whole educational system?

High quality research of fundamental educational principles **and** a well-planned and continual implementation and redesign process will provide answers to these questions. While there is much work to be done, the good news is that these questions are well defined and give a clear focus to the problems at hand.

The Constraints

Creating any kind of education program requires a balancing of many forces at work, including political, social, ethical, and practical considerations. Below are listed a few of the most important "constraints" on the solution to creating an effective teacher preparation program. *It is important to keep in mind that the ultimate goal is to establish and continue a teacher preparation program which maximizes student achievement, and any other constraints must demonstrably contribute to this goal.*

Research Results

While there is much work to be done, there is already a significant amount of research which indicates important directions we can follow to begin the process of establishing an effective teacher preparation program.

- First, several essential components for a program which produces effective teachers have already been identified. They include high academic performance[3], deep understanding of content knowledge[4], and subject-specific pedagogical methods[5].
- Second, a significant amount of research has revealed effective methods for teaching and learning specific topics in Physics, Mathematics, and Chemistry. Interestingly enough, this research has been lead by both scientists within the fields and educators alike. This research reveals that many misconceptions are very particular to a specific topic or concept within a subject, and that understanding and "undoing" the student's misconceptions requires a detailed knowledge of that specific topic and the misconceptions often associated with

it.[5,6] This research also reveals that allowing the students to become actively engaged in the classroom, via modes such as inquiry or cooperative learning, produces higher student achievement, especially in conceptual understanding.[6,7]

- Third, educational research has revealed that "teachers teach as they were taught", implying that the best way to train teachers is to teach them in ways which model effective instruction.[8]

Professional organizations

Organizations such as the National Council of Teachers of Mathematics (NCTM) and the National Science Teacher Association (NSTA) have recommendations for effective teacher preparation program, based on a mixture of research and vast experience in the classroom. These recommendations include specific standards for content knowledge, reasoning and pedagogical skills. These standards are also often seen as the benchmark by accreditation associations and state legislatures.

Professional scientific organizations such as the National Science Foundation (NSF) and the American Mathematical Society (AMS) also have recommendations for teacher preparation programs and content curricula. These organizations are comprised of the content experts (mathematicians and scientists), and have a deep understanding of the important topics in content areas.

The University Environment

In many Universities across the nation, there has not been a bright history of strong collaboration between the colleges of the Arts and Sciences and colleges of Education. In fact, in many cases there is very little if any cooperation between the two. However, it is now being widely recognized that cooperation is essential, and many institutions are beginning to forge cooperative ties between the colleges.

At the classroom level in the University, many classes are taught in the traditional lecture method, which has been shown to be an ineffective learning environment for many students. These courses are especially inappropriate for prospective teachers, who need to be taking courses taught in a manner which models effective pedagogy. In short, many of the standard courses at the university level are

not well suited for prospective teachers. One should note on the positive side, however, that many departments are beginning to offer courses which are taught using research-based, effective pedagogical methods.

Supply and demand

There is a growing shortage of qualified Math and Science teachers, especially at the middle school level. Poor retention of teachers, especially within the first five years in the profession, represents a significant portion of the shortage.[9]

Local Issues

The OSU College of Education has adopted a Masters of Education program, and there are currently no undergraduate education programs in the major content areas (English, Math, Chemistry, etc.), though prospective secondary school teachers, for example, typically obtain a B.S. or B.A. in the subject area they wish to teach. Currently, there is no undergraduate major which is well aligned with the new Middle Childhood licensure content requirements.

The Initial Solution: designing a major program

With these constraints in mind, the College of Mathematical and Physical Sciences has set out to establish a major specifically for prospective Middle Childhood Math and Science teachers. This major program is being formed in collaboration with the departments of Chemistry, Geological Sciences, Math, Physics, the College of Biological Sciences and the College of Education.

The program has three major goals

1. **Provide students with the foundational knowledge and experience of math, the natural sciences, and pedagogy necessary to become an effective middle childhood math and science teacher.** The program contains, as much as possible, courses and curriculum which model effective teaching and are based on interactive, real-world problem solving. Continual assessment and improvement, in collaboration with the education research

community, will be a hallmark of the program.

2. **Fulfill the recommendations of professional organizations and state math and science requirements for MC teachers.** In fact the major goes well beyond the minimum state requirements and provides the students with additional math and science courses which will broaden and deepen the students understanding of math and the sciences, and will provide a solid foundation for their continuing professional development as science and math teachers.
3. **Dovetail with the OSU Masters of Education program for Middle Childhood Math and Science Education, allowing a student to complete a B.S., M.Ed and all licensure requirements in 5 years.** This undergraduate major program alone does not meet all of the requirements for MC licensure. In order to obtain a license the student will also need to complete a state-approved teacher preparation program which provides additional courses in pedagogy and intensive classroom experience. For example, the student with a sufficiently strong record may enroll in the Master's of Education program at OSU, and upon completion (4 quarters) he/she will have a license to teach. The proposed major is designed to dovetail with the OSU M.Ed. program, and includes some pedagogy courses. Ideally, these pedagogy courses will also count towards the M.Ed. and streamline the whole teacher preparation process. In addition, a coherent 5-year program will allow the University to proactively recruit prospective teachers.

Brief description of the major program

The key to this program is providing as many courses as possible that model effective teaching. Ultimately, if all courses are taught in this way, then no special content courses would be needed for prospective teachers, though there would still be a need for courses which study pedagogical issues for a specific content area, and these could be offered in close collaboration with education experts. One of the major tasks at hand, then, is to facilitate revision of those content courses in each of the departments that do not model effective teaching. Since this is a large, long-term undertaking, it is also important to identify a few key courses that could be changed to better suit the needs of prospective teachers. This is the small first step taken in

creating this program, keeping in mind the larger goal of effective teaching in all courses.

Another important concept is one of creating a community of prospective professional educators to aid in recruitment, retention and overall excellence. This program plans to achieve this through collaborating with the College of Education to create a coherent 5-year program (B.A.-M.Ed.), recruiting at the high school and undergraduate level, maintaining high standards, and by creating cohorts of prospective teachers to take classes together in special sections.

The Math and Science Middle Childhood Education curriculum is comprised of three key components:

Math Core

In addition to the courses already designed for elementary teachers, this includes a calculus course and a real-world math course that will be revamped to better suit the needs of prospective teachers.

- 29 credit hours of Math, including 2 courses designed for elementary teachers, an everyday-life problem-solving course, a survey of calculus (designed for teachers), and two problem-solving based courses in algebra, trigonometry, and functions, with many real-world applications.
- 5 credit hours of Introduction of the practice of Statistics
- 4 credit hours in Elementary computer programming and problem solving.

Science Core

In addition to the two physics and one geology course designed for teachers, several of the following courses, including the Biology and Chemistry courses, are undergoing (or have already undergone) revisions to model more effective teaching methods

- 10 credit hours of Introductory Biology.
- 10 credit hours of General Chemistry, 5 credit hours Chemistry Elective.
- 18 credit hours of Geology, including physical and historical geology, an advance elective, and a field experience designed for teachers.
- 10 credit hours of Physics. This research-based series uses the inquiry method and is design for K-8 teachers.

- 5 credit hours of advanced science elective, 5 hours of advanced Biology elective.
- 5 credit hours (3 quarters) Research Capstone.

The research capstone course is a newly proposed course which will provide the students with the opportunity to perform and experience scientific research, enabling them, as future teachers, to model and better understand effective math and science teaching. Over the span of three quarters, the students will design and implement a small research project, collect and analyze the data, present the results, and finally reflect on the experience—especially as it pertains to the nature of science and the teaching and learning of science. The course will be offered by science and math faculty.

Education Core

This component is designed to introduce the student to education theory and practice at an early stage, in order to help build the appropriate context and integrate ideas of content and pedagogy.

- 6 hours Field Experience in the schools
- 12 hours Upper level Education and Cognitive Psychology courses. These courses will help to fulfill the requirements for the M.Ed. and licensure programs.

Continuous feedback: assessment and redesign

The creation of the major program is only the first step in a successful program for teacher preparation program. This program will use feedback from visiting K-12 teachers, field experience programs, and data from a post-graduate career support program to assess and redesign the program. Redesign will include curriculum revision as well as possible revision of individual content courses, which will be done by working closely the departments.

Integration with other programs

Besides integrating coherently with the OSU Master's of Education program,

this program may create and integrate with some of the following program possibilities

- Undergraduate Field experience program extended into specific schools for long term research of effectiveness.
- Transition program to support teachers for the first several years in service.
- Master teacher program: inviting several master teachers to OSU for on eyear to help design and run the teacher preparation program.
- Professional Development of current teachers: integrate teacher preparation program with a long term professional development program.

Conclusions

Given that 'teachers tend to teach as they were taught' and that most science and math courses are taught in traditional methods that have been shown to be ineffective for many reasons, especially in the Universities, there is a 'vicious cycle' of poor math and science education within our K-16 system. It appears that the necessary and perhaps the most effective place to break this vicious cycle is within the University science and math departments, especially in teacher preparation programs. Breaking this cycle is no small task, and will certainly require patience, sound research, and dedication to excellence over the long term. By utilizing courses that already model effective teaching, by working with faculty to revise traditional courses, and by systematizing an assessment and redesign process for the program, we can begin with a feasible program to prepare teachers who can lead students to achieve their maximum potential in math and science.

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Redesigning a General Biology for Non-Science Majors

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Many successful efforts to redesign biology courses for non-science majors have been previously carried out, and many more are currently underway. The goal of this paper is to describe our experiences with attempting fundamental change in the General Biology course for non-science majors at the University of Cincinnati. It is hoped that this description will provide some insight and efficiencies for those either currently attempting change, or desiring to do so in the future. In format, we have followed a model used at the RISE (Redesign in Science Education) conference held at the Ohio State University October 20-21, 2000. The primary goal of the Conference was to bring together individuals interested in principles upon which redesigned courses, curricula, programs, and system-wide efforts could take place.

What was the state of affairs prior to our redesign efforts?

At the University of Cincinnati, several of its colleges have been teaching a three quarter sequence (three credits/qtr.) General Biology course for many years that allows students to partially satisfy the Natural Science requirement common in many of the colleges. While class size varies a good deal depending upon the college, it is typical that the Arts and Sciences General Biology course has over 350 students. The course is taught in the usual large auditorium, three times per week for 50 minutes each session, with the "sage on the stage", no opportunity for small group interactions, and a content that surveys the range of the biological sciences. Sound familiar? We don't know how many of these courses are still left around the country, but the process and outcome were sufficient motivators to encourage us to think about change beginning in 1992.

What problems existed that necessitated a redesign effort?

The need for change was obvious from at least these two perspectives:

(1) The process of only using lectures to this large number of students suggested that relatively little learning was occurring, since the students were not actively engaged beyond accumulating their notes. The educational literature is clear that lectures have the advantage of providing a good deal of information, but that other forms of pedagogy are also necessary if real learning is to occur.

(2) Much of the content in surveying biology had little relevance to the students' lives; thus, it was not connecting most of the information to what they already knew. While the information might have stayed in short term memory long enough to adequately respond to exams, little of it reached long term memory to enhance real learning.

Thus, the general framework for how the course was offered is incompatible with most of what the educational literature tells us about how students learn, and what the "ideal" classroom looks like. The literature is clear that using a variety of different pedagogical tools promotes learning to a much greater degree than using only one method of instruction, no matter which method that might be (reference). It also clearly indicates that students actively involved in the learning process do a much better job processing information than if they are only passively involved (reference). And the literature is also clear that offering content that connects to what students already know results in a great deal more long-term retention and learning than if no connection occurs (reference). These are simple, common-sense, ideas that are easy for all to us to accept because we experience them ourselves on essentially a daily basis. When we hear or read something about which we know very little, it is likely we retain this information for only a short time—or sometimes not at all!

What were the principles guiding our redesign effort?

The need for an informed and educated citizenry

America has evolved into a scientific and technologically oriented society facing problems and issues which were inconceivable only a few decades ago. Citizens are asked to make decisions about issues that range from dealing with new diseases, addressing environmental health problems, choosing proper diets, responding to

genetic engineering, utilizing forensic DNA, to deciding whether to vote for political leaders who support science research. Many of these and related decisions are well-informed or ill-informed depending upon one's knowledge of biology.

Unfortunately, many citizens are not biologically literate. They have neither the formal education nor life experiences that enable them to understand the living world around them. The problem is even evident among some of our brightest and best. Academically oriented students pursuing college degrees seldom choose science-related majors. In an annual survey of college freshmen, students were asked to select their career plans from 15 choices. Approximately 10% of the 1990 freshmen intended to pursue careers in science and engineering. Of this 10%, 8% preferred engineering; approximately 2% opted for scientific research (1).

Evidence that many students are not satisfied with their biology courses

Even though most college students do not choose science majors, they do take some biology courses. In the above study, about two-thirds of the arts and sciences majors took one or more life science courses. Slightly more than half of the business majors did the same. The average number of life science courses taken by non- science, non-engineering students was two (1). Yet in 1988, the Higher Education Research Institute at UCLA asked selected students who were freshmen in 1984 to rate their levels of satisfaction with courses and instruction (2). Approximately 40% of the students were not satisfied with the courses they had taken in science and mathematics. Moreover, numerous studies of science education over the past decade (e.g., AAAS Project 2061, National Science Teachers Assoc. Scope and Sequence, National Science Foundation The Federal Investment in Science, Mathematics, Engineering, and Technology Education: Where now? What next?) have documented the need for change in our presentation of science generally, and biology particularly, throughout the formal education system. The conclusion is clear: a small percentage of college students major in science; most non-science majors will take at least one biology course; the need to vastly improve these offerings is well documented.

Desire to respond to these realities

In 1992, it seemed clear to us that by gathering together a team of biologists and a science educator, substantial improvement could be made in the non-science majors

General Biology course to help resolve these issues. The AAAS report recommended attention to content that is meaningful and relevant to students. They defined biological literacy as understanding a small number of pervasive biological principles appropriate to making informed personal and societal decisions (3). In addition to carefully selected content, biological literacy requires mastery of the critical thinking skills needed to analyze and evaluate biology-related information in real life settings. Using instructional approaches that develop these skills we felt would facilitate achievement of biological literacy. Students would also believe that they are capable of understanding biology-related issues and potential solutions which are recommended by biologists. The students might also develop positive attitudes and values toward biology.

In addition to changes in content, educational researchers and practitioners agree classroom instruction is more effective when pedagogy extends well beyond a lecture only model. For example, learning improves when students interact with the teacher and with one another. This is most likely to occur if teachers use students' ideas during class instruction, organize material in understandable ways, summarize information frequently, ask questions and wait for students to respond, and exhibit enthusiasm for the material being taught (4). Science instruction is also more effective if concept presentation is sequenced from concrete-to-abstract. This can be accomplished by first engaging students in relevant exploration activities, followed by teacher-centered presentations that clearly demonstrate the utility of scientific principles to organize ideas, followed by opportunities to experience broader applications of these ideas. This sequence is called the "learning cycle." Using the learning cycle to teach science is an effective way to present content while developing critical thinking and problem solving abilities. The learning cycle is consistent with the nature of science (inductive instead of deductive) and fosters student involvement in the learning process (5, 6).

To achieve this, we wanted to establish a classroom climate that encourages participation and risk taking. Such a climate supports student efforts to understand new ideas, especially when the new "understanding" requires students to discard previously accepted concepts and principles (7). The combination of a carefully developed curriculum which focuses on a small number of pervasive biological principles appropriate for students to make informed personal and societal decisions, and of instruction which is delivered in ways that maximize student involvement, can

increase the biological literacy of non-science majors. The purpose of this project then was to develop, implement, and evaluate such a course, and to extend those successful components to other institutions as well.

What specific actions did we take in the redesign effort?

Initial steps

The first tasks were to develop a team of interested and capable biologists and a science educator, to have this team learn how to communicate with each other, and to agree on the best resolution. Given the voluntary nature of the endeavor, this took approximately the year of 1993. Contacts were also established with the National Science Foundation, and the decision was made to write a grant proposal to NSF for support of the project. Writing the proposal took approximately six months, and was submitted in June, 1994. The initial proposal was not funded, but the reviews gave valuable insight on how to redesign the proposal, so a revision was submitted in June, 1995. Initial interest from NSF was expressed during that fall, with negotiations continuing until the grant was awarded to begin August 1, 1996. Of the initial $792,000 requested, NSF awarded $400,000, with the additional commitment that several CD-ROMs would also be produced.

Creation of the new course: Biology in a Human Context

The first goal of the project was to create, fully develop, implement, and evaluate a new and innovative, year-long biology course titled: Biology in a Human Context. The resulting three-quarter sequence course is currently an alternative to the existing Biology sequence for non-science majors described above, but it is hoped that the new sequence will eventually replace it. Initially the course was designed as 4 credits per quarter, with three hours per week of Assemblies (all students together), and a two-hour Practicum (limited to 25-30 students/section). Since the university coursework is built upon a three hour or five hour model, this was not well received by the students, so it was changed to a five hour/qtr sequence last year by adding an additional hour to the Practicum period each week. The advantage of this is that students can now fulfill the natural science requirements of all colleges with this single course. This is the first non-science majors course at the University of

Cincinnati to fulfill this 15 credit requirement in one year, and makes it equivalent in this sense to the typical biology and other introductory science courses for science majors.

These efforts were carried out by all members of the team working together, although a number of specific tasks were assigned to either a sub-group of the team, or to specific individuals.

What is different about the course than what existed before?

Different Pedagogy

Our desire from the outset was to respond to the educational literature by dramatically changing both the pedagogy and the content of the course. The Assembly periods on average have the following percentages of time committed to various pedagogic activities:

Activity	Percentage of time
Lecturing	35
Course Management	5
Exams, and review	15
Biology in the News	15
Videos	10
Large group discussions	10
Small group discussions	10

Biology in the New is an offering in essentially each Assembly period of how recent biologic events may be impacting our lives. These are typically presented as short segments of video from one or more of the national news networks such as CBS, NBC, or ABC, taped at home within the last week before the Assembly. The topics are endless, such as:

- Sixth billionth human being added to planet (during the fall of 1999)
- Gene therapy to treat heart disease
- Sequencing the first human chromosome
- World AIDS day

- Race to decode the human genome
- Genetically modified foods
- Thomas Jefferson fathering Sally Hemings children
- Trans fatty acids on labels and in the diet

Other videos are also shown within Assembly that are typically purchased commercially, and vary in length from 5-15 minutes. Discussion of both Biology in the News items, and the other videos, varies from a few minutes to perhaps 20 minutes or more, depending upon student involvement, the topic, and the quality of the discussion. It is not uncommon for extra credit assignments to result from the discussion if questions are raised that no one, including the instructor, can answer.

The Practicum periods vary considerably from week to week, but almost always are hands-on activities. They include: fieldtrips (currently five of the 30 Practicums during the year); laboratory experiments that typically don't require a wet lab; project development and presentations; internet and CD ROM activities; pedagogically useful review of exams; small group work; and additional videotapes with discussion (questions are handed out prior to the video being shown, and provided the basis of at least the initial discussion).

Different Content

Besides these pedagogic changes, we have also changed the content signifi cantly, moving much more to a literal interpretation of the course title: *Biology in a Human Context*. The fall quarter emphasized physical well-being of the individual by looking at personal health through diet and nutrition and the digestive system, homeostasis, and diseases such as AIDS through the immunity system (the scientific process is also emphasized, as are the characteristics of life and death, including review of the Role vs. Wade decision on abortion, and euthanasia through discussion of Dr. Kevorkian and Death with Dignity Act in Oregon). Winter quarter emphasizes the family through discussion of human reproduction, meiosis, Mendelian genetics, pedigree analysis, gene and diseases, biotechnology and the human genome project, genetic engineering to produce products useful to humans, geneticallymodified foods, STDs, assisted reproduction technology, and birth control.Sprin quarter emphasizes the population and community by including human population growth, ecosystems

and biomes, the importance of biodiversity, effects of humans on the Earth, the origin of life, and human evolution. The overriding theme throughout the entire sequence is organic evolution, and how the biologic world of today has come into existence as a result of Darwinian evolution.

Critical Thinking and Writing Exercises

Biodiaries --using writing as a way to learn. Examples of these are:

- Roe v. Wade decision on Abortion
- Kevorkian, and Physician Assisted Suicide
- Nutritional Analysis of student's food intake
- Karytoype analysis of unknown aneuploids
- Iceland's Gene Pool controversy (first surfaced in 1999)

The specific course objectives, student assignments, and other course details are available at the course web site (http://www.oz.uc.edu/bionsf).

What gains in student achievement occurred as a result of this project, and how were they measured?

In addition to the standard student evaluation questions, a more extensive instrument was developed that asked students to indicate how much they liked the above changes, and how much they learned from them. Additionally, a 66 item questionnaire was developed as a Biology Student Survey. This was given both as a pre-test at the beginning of each qtr, then again as a post-test at the end of each quarter to measure whether changes occurred in students' knowledge, attitude, or practices as a result of the course. Other forms of course evaluation included formative evaluations during the middle of the quarter, class observations, and focus groups, these latter two being carried out by personnel not part of the instructional staff.

All measures of evaluation produced similar results, and indicated that the students' assessments of the content and instructional procedures were quite positive. On a scale of 1-5 with 1 being the highest, the average response for all three quarters was 1.8 to the important questions of: "Attending class contributed significantly to

my learning the material", "Overall I would give a high rating to the instruction in this course", and "I would recommend this course to other students". Observations of classes revealed that students had opportunities to master the themes identified during course development, retention rates were higher than in traditional biology courses for non-science majors, and student success rates exceeded those of the traditional course for non-science majors.

Additional positive aspects of the course besides the students' affirmative responses are:

- faculty from six different colleges were engaged in planning and delivering the course, thereby utilizing inter-college collaboration
- the course meets the criteria established by the General Education committee for Gen Ed credit by using instructional approaches that engage students, involves them in critical thinking, encourages them to use writing as a means to learn, and helps them make connections between biology and other areas of study
- the course is recognized as a "model" course for future teachers by both the College of A & S and the College of Education for K-9 teachers
- the connections between A&S and the College of Education are further reinforced by a "Bridging course", which connects *Biology in the Human Context* to the training of middle-level pre-service science teachers. This one credit course each quarter is designed to help these pre-service teachers translate what they learn in *Biology in a Human Context* into curriculum units that will be further refined in their College of Education methodology courses, and ultimately utilized in their own classrooms. This simple but eloquent opportunity for these budding teachers is showing how content courses in Arts and Sciences colleges can be effectively linked to pre-service training within Colleges of Education.

What modifications should be made to this redesign effort before others attempt it?

Because of the effort involved in faculty learning how to effectively communicate and work together to improve teaching, team efforts such as this take considerable time to accomplish even modest improvements. Thus, finding the time to allocate is critical. This may be accomplished through a grant which offers summer

salary, which was our approach, or perhaps through release time provided by visionary administrators. Still, we found the time commitment significantly greater than anticipated, so this should be considered during the planning stages.

Two major considerations to which we did not give sufficient time should be critical components of any redesign efforts. First, we did not pay sufficient attention to bringing other colleagues on board within our respective departments. This resulted in isolation of our efforts within departments even while we were effectively communicating among ourselves. This recommendation is consistent with what Sheila Tobias, a well-known science educator has found in successful undergraduate programs. After studying dozens of science departments around the country over a two year period that had programs which worked, she stated (8):

> ***In place of perfect or near perfect curricula, pedagogues or instructional devices, I found…. that the significant variable in the successful undergraduate science programs I studied was this one: the willingness of the department-based faculty to take collective responsibility for the quality of their undergraduate instruction overall.***
>
> .....in those departments where programs work, teaching (and not just individual teachers) is the subject of intensive and continual departmental review.

We are now dealing with the realities of not having paid closer attention to these findings.

The second recommendation is to consider not only implementation of the redesign from the beginning, but also *institutionalization*. When grants end, administrators from department heads to provosts are likely to find other pressing needs for resources that are necessary to continue the redesign efforts. And typically, redesign that results in improved learning for students will likely require additional resources to sustain. Should these resources not be available, the enormous efforts expended in the process may prove to be ephemeral.

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The Education Of Physics Graduate Assistants

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Introduction

Research oriented colleges and universities that have large undergraduate and graduate programs and employ graduate students as teaching assistants occupy a strategic position in the educational system. They are sources both for new research results and for new teachers at all levels. They have also been the objects of publicly expressed concerns about the relative importance they assign to research and to teaching, and about the need for revising and upgrading instructional programs, including a reassessment and revision of graduate programs, to meet the challenges of changing conditions in society.

Preparation for the Role of Teacher

Why should we bother with formal programs for the preparation of physics graduate students as teachers? If, as the proverb has it "Poeta nascitur, non fit – A poet is born, not made" is this not also true of a teacher? This question has been addressed by previous generations and it is instructive and sobering to look at some of their answers . New answers have evolved in each generation with the evolution of our knowledge and understanding of the processes of learning and teaching. Moreover, recent advances in the cognitive, social and psychological sciences enable one to say that :

> *"The body of research on the cognitive and social processes that underlie the learning and performance of individuals and teams has grown to the point that it is a far better guide to training than is intuition or standard practice. In an era of global competition and information superhighways when the survival value of being able to*

learn and change is greater than ever before, it is crucial to draw on these resources to enhance training."

In particular, the last two decades have seen the growth of an international community engaged in research in physics education. Systematic study of student understanding has yielded important information about the difficulties that students encounter in learning physics and about effective instructional strategies for addressing these difficulties. There is by now a steadily growing research base that can serve as a resource for the improvement of physics instruction.

Program Design

Any departmental program for preparing graduate students for a role in instruction will have unique features since it will have to take into account local short-term and long-term needs and constraints. In the short-term there is a pressing need to help novice teachers learn "survival skills" within the existing system. In addition to fulfilling whatever responsibilities they may have in instruction, graduate assistants are expected to move expeditiously through the sequence of formal courses, examinations, and research work which leads to an advanced degree. Many new graduate assistants, particularly those from other countries, find themselves working under a set of expectations and pressures which exceed in magnitude and differ in kind from any they have previously experienced. But the education of teachers needs to go beyond the short-term goal of minimal survival skills. Just as important is the need to provide for all teachers – and to build into the program itself – the long-term elements of broad perspective, and of self-improvement and self-renewal that will keep the teachers, and the system, healthy and effective and prepared to take advantage of change – as well as to cope with it.

In the design of a new program, or in the revision and up-dating of an existing program it is important that careful consideration be given to establishing, at least as a starting point, a clear understanding and a clear statement of what it is that one wishes to achieve. One must give equally careful consideration to the nature and implementation of the feedback and assessment processes necessary to provide pertinent and timely information about how the program is working, the direction in

which it is moving, and what changes may be appropriate. It is not only in sailing and space flight that continuing mid-course corrections are essential. Planning must also involve a realistic appraisal of the context in which the program is to be carried out, of the extent and quality of faculty and administrative support, and of available resources of space and of time, of finances, and, especially, of personnel. The old adage has it that "There is one thing that each of us knows better than anyone else – that is where the shoe pinches our foot". If we wish to understand how graduate students (and undergraduates) perceive their needs and difficulties, we need to include them in the design and assessment processes from the very beginning. Experience has demonstrated that they can bring to the these processes valuable points of view, insights, and creative approaches that might otherwise have gone unrecognized or inadequately appreciated. Likewise, undergraduates who have gone through the courses involved can make significant contributions to "reality checks".

Resources for programs for the preparation of graduate students for their teaching duties exist at various levels: general, institutional, and disciplinary department – with corresponding levels of specificity. The general literature is truly immense and resources are available in a variety of formats, both print and non-print, including books, journals, conferences and their proceedings, bibliographies, workshops, sample programs, and electronic communications. There is also a substantial overlap with national programs for new faculty. In particular, "Preparing Future Faculty:" is a program of The Association of American Colleges and Universities and The Council of Graduate Schools which works to create model graduate programs to prepare future faculty in five academic disciplines, including physics. Information is available online at http://www.aapt.org/programs/pfpf.html

It is perhaps unnecessary to comment on the great and growing importance of the Internet as a resource. From Applets and audio to e-mail and multimedia to video and virtual reality, the Web makes possible the exchange of information with unprecedented rapidity and scale.

Institutional Resources

Almost every university and college has an "Office of Faculty and TA

Development" or a "Center for Teaching and Learning" which provides campus-wide programs of assistance to faculty and TAs. Most institutions also have an "Office of International Student Affairs" and an "Office of Disability Services" which provide useful information and support in these areas. Significantly, most of these organizations have web sites on their college or university servers. One listing at the University of Kansas provides links to about 200 such programs in 44 states. http://eagle.cc.ukans.edu/%7Ecte/resources/websites.html

The resources thus available include institutional Handbooks for TAs, syllabi for TA training courses, Bibliographies on Teaching and Learning, book reviews and occasional papers on a wide variety of relevant subjects. These sites are a potentially important source of information and resources, and web surfing among them can uncover much useful material most of which may be freely downloaded

Disciplinary Resources

Among the sciences, physics has been in the forefront in responding to the need for change. In the past decade or so there have been many innovative curriculum developments, national conferences and workshops, and national proposals for the reform and revitalization of instructional programs. A comprehensive review of these developments and an extensive listing of references has been published in the American Journal of Physics as Resource Letter **EPGA-1**: **The education of physics graduate assistants** (*American Journal of Physics* **68**, (6), June 2000, pp. 502-512). This article may also be downloaded from the Web as a PDF file at the URL: http://www.physics.ohio-state.edu/~jossem/AJP502.pdf

Departmental programs tend to fall into two general categories: (a) programs directly connected with a specific course or course sequence, usually at the introductory level, in which many of the graduate assistance teach, and (b) programs of a more general character involving formal course work in physics education, often as a part of an advanced degree program in the field. In contrast to the volume of material at the general and the institutional levels, relatively little has been published about individual departmental programs in either category. Perhaps this may be so because, in some sense, helping someone to learn how to teach well is more easily done than said, and the process is more of an apprenticeship in which, as Picasso put

it. "What I do not know how to do, I learn by doing."

In contrast to training programs keyed to ongoing individual introductory level courses, programs for preparation of graduate students for a career in teaching and research in physics education may include formal courses and seminars at the graduate level which run for a semester or more. Such courses offer the opportunity for a deeper and more comprehensive view of physics education. At this level also the opportunity presents itself for the active involvement of the graduate students as colleagues as well as students. In his Milkman Award Lecture *"Teaching and Learning,"* Frank Oppenheimer remarked that "There are two things that teachers must do well. They can set up environments that are conductive to learning, and they can help students get un-stuck. It is difficult to be more specific."

Individual courses will answer to local needs and boundary conditions, but actively involving the graduate students in the design and implementation of the course, and having the course itself model for them some of the many ways in which one can "set up environments that are conducive to learning" and "help students get unstuck" are useful points of departure.

The old basic questions "What shall I teach?" and "How shall I teach it?," and the more specific questions that follow from them, are germane at all levels of instruction and suggest a wide variety of topics for study and discussion in the areas of, for example, curriculum development, learning and teaching styles, student and teacher characteristics, motivations and attitudes, instructional methodologies and technologies, lectures and lecture demonstrations, tutorials, cognitive studies, concept formation, problem solving, laboratory work and laboratory safety, examinations, assessment, evaluation and other feedback mechanisms, mentoring, the history, philosophy, cultural and societal aspects of physics, the interactions of physics with and its relations to other disciplines, and research in the field of physics education.

With an increasing number of programs in physics education research appearing in physics departments around the country more such courses are coming into being. Here again there is no "one-size-fits-all," and syllabi for such courses necessarily reflect the philosophies and viewpoints of the individual programs.

As has been noted previously, there is no "one-size-fits-all" permanent solution for departmental programs for preparing graduate students for a role in physics instruction. Each program will have unique features answering to the details of local

circumstances, local curricula, and the myriad of other local short-term needs and constraints. It is, however, a commonly observed characteristic of successful programs that, while answering to the local conditions, they involve graduate students as partners in the enterprise, that they have strong departmental and institutional support, and that they have effective feedback mechanisms for continuing self-assessment and revitalization. It is apparent also that the most important and valuable resource for any such program lies in the imagination, creativity, empathy, patience, persistence, and just plain hard work of those who design, create, and work to sustain and improve it.

Developing and Implementing a Critical Inquiry Approach to a Large, Existing Introductory Biology Program at a Research I University

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Science teaching, especially at the underclassman, undergraduate level at the Ohio State University in the past has probably been accurately portrayed, at least to a first approximation, by the Boyer Report (ref). The science colleges of OSU have taken introspections such as those of the Boyer Report and AAAS's Project 2061, NSF's "Shaping the Future" initiative, and the Howard Hughes Medical Institute's "Beyond BIO 10" initiative seriously. Here we describe an ongoing collaborative initiative to meet the changing needs of students--majors and non-majors--who enroll in courses offered by the Introductory Biology Program (IBP) at OSU. Many of the needs we are addressing and solutions we are developing are not unique, indeed most are universal (see for example the similar programmatic description from our sister institution the University of Cincinnati elsewhere in this report); with opportunities to develop alternative solutions based upon the distinctive competencies and needs of individual institutions.

Major Programmatic Goals

Our efforts at reforming biology education at the introductory biology level are founded on several pedagogical principles well established in the literature and emphasized in recent calls for educational reform (e.g. those listed above):

- Students learn best by doing; laboratory exercises must be integrated with "lectures".
- Inquiry is not memorization. Inquiry must be mentored; memorization must be practiced.
- Learning is the application of insights gained in one context in a new context. It, too, must be mentored; it cannot be memorized.
- The important "facts" of biology are best understood when organized upon a logical framework understood (indeed, built) by the student.
- How we know something is "true" is as important as knowing that it is.
- Evolution is the unifying principle of biology and rest of the historical sciences.

Audience

The IAP teaches about 8,000 students per year. A majority of these are non-majors fulfilling OSU General Education Curriculum requirements. They register in BIO 101 (a basic survey course; ca. 1,200 students/quarter) and BIO 102 ("Human Biology"; ca. 300 students/quarter). Majors in most other degree programs in the College of Biological Sciences take the BIO 113 (450 students/quarter) and 114 (300/quarter) sequence. This is currently a traditional "large to small" survey with some coordination between lecture and lab and varying emphasis on classical didactic approaches depending upon instructor (with instructors drawn from all disciplines within the CBS). Honors students (150/quarter) enroll in a similar sequence, BIO 115 and 116.

Within BIO 101, our largest course, 30 % of students with declared majors are in social and behavioral sciences, 23% are in the humanities, and 18% are in journalism.

Surveys of the academic majors of students within our other courses are underway.

Since OSU embraced the "Holmes agenda" in 1991, it is no longer possible for us to identify students with declared education majors in our courses. Nonetheless, we regard such pre-service students as our single most important clientele. We do this for two reasons:

1. The literature is clear that teachers teach they way they were taught. If we

expect K-12 teachers to teach science the way science is done, then we must mentor that approach to them whether the IBP courses they take represent the majority of college science course they take (elementary teachers) or the gateway to their general biology/general science major (middle and high school teachers).

2. By "targeting" the needs of students who will go on to be teachers, we feel we better meet the needs of all other students with a diverse set of college majors who enroll (are often required to enroll) in IBP courses. Meeting the perceived needs for pre-health (especially pre-medical) major student has been conveniently cited by some university-level faculty as the primary reason for retaining the didactic, memorization-laden approach to introductory biology courses, especially those offered for majors. To the extent that such a view is correct (and this is in serious question), such needs can be met by students and their instructors in advanced courses which have less focus on "surveying" biology and its major themes (such as evolution) and approaches.

Ongoing and planned pedagogical modifications of IBP courses

A growing core of faculty and staff from the College of Biological Sciences and the College of Education has initiated a coordinated plan to make all of the courses by the IBP be model examples of undergraduate science education reform in the country. Some of these will be described in more detail at the RISE conference.

- A model syllabus for BIO 101 has been developed which emphasizes:
  - X Open-ended and critical inquiry
  - X Student designed experiments
  - X Introduction of new concepts in laboratory exercises
  - X Subsequent elaboration and application of those concepts in "lecture".
  - X Cooperative learning.
  - X Learning cycles
  - X Little or no memorization.

- Development (in association with OSU's Program in Faculty and TA Development) of a teaching assistant workshop for new teaching assistants made

possible with funding from Ohio's SUSTAIN program.

- A similar workshop for faculty is planned for summer 2001.
- Increase in relevancy of biological information used in the course (The New York Times will become a required reading for BIO 101 students in Winter quarter).
- Effective and appropriate use of computer technology in laboratory exercises (e.g. for real time access to data bases such as NIH's Genbank.
- Planned development of a "text" (real and virtual) consistent with and supportive of the above goals.
- Ongoing assessment of the above goals.

OSU's Introductory Biology Program is interested in working with partners, both within and outside OSU in this effort to reform our science teaching efforts.

Teaching High School Physics

William Heinmiller
Westerville City Schools, Westerville, Ohio

(See addendum)

Session IV.

Professional Society and State Level Initiatives

The Role of a Science Education Research Journal in Redesign

Charles Anderson

JRST editor, Michigan State University

(See addendum)

The Redesign of a Professional Organization to Support Redesign in Science Education

Julie Gess-Newsome
President – Association for the Education of Teachers in Science
Director – Science and Mathematics Learning Center
J. Lawrence Walkup Distinguished Professor of Science Education
Northern Arizona University

The Role of Professional Associations in the Redesign of Science Education

Professional associations exist to promote efforts within a field and to support the work of their members while achieving these goals. There are numerous professional associations in the area of science education, all with their own unique personalities, goals, organizational structures, and member expectations. For instance, the National Science Teachers Association (NSTA) has the mission "to promote innovation and excellence in science teaching and learning for all." The National Association for Research in Science Teaching (NARST) is "committed to the improvement of science teaching and learning through research." Both organizations serve an important role in the science education community and both are vital to redesign efforts in science education. The Association for the Education of Teachers in Science (AETS), while embracing research and the improvement of practice, is unique in its mission, "to promote leadership in, and support those involved in, the professional development of teachers of science." Different from other associations, AETS has committed itself to broadly defining and actively recruiting:

> Educators involved in the professional development of teachers of science, including science teacher educators, staff developers, college-level science instructors, education policy makers, instructional materials developers, science supervisors/specialists/coordinators,

> lead/mentor teachers, and all others interested in promoting the development of teachers of science (AETS Mission Statement).

As an organization, AETS is a facilitator in the redesign of science education. Dedicated to the professional development of science educators, AETS helps nourish and sustain the individual efforts of its members throughout the academic year. Providing opportunities for collaboration, education, and stimulation occur through its publications and national and regional meetings. By supporting and disseminating the individual efforts and accomplishments of its members, AETS hopes to have a collective impact on the redesign of science education.

Impacting science education implies a direction for change. Agenda setting for the redesign of science education is accomplished within AETS in three important ways: through its mission, its members, and sensitivity to local and national contexts. The first mechanism is formal and purposefully broad in scope and design. The second two are changing and require a level of organizational responsiveness that is not easy to achieve. For instance, the AETS Mission Statement identifies five actions that will lead to achieving its mission:

> To accomplish its mission, AETS will be the primary voice for science teacher education
>
> 1. by identifying and suggesting key actions on issues in science teacher education.
> 2. by setting policy for the development of teachers of science.
> 3. by collecting and disseminating information about the needs of teachers of science.
> 4. by collecting and disseminating information on the needs of science teacher educators.
> 5. by setting policy for the development of science teacher educators.

These statements help guide the actions of the AETS leadership as they consider alternatives within the organization. For instance, forming affiliations with other professional associations, sponsoring sections in professional journals, or considering the need for political action can be evaluated against these principles.

Few members, however, could state these principles or cite how they influence their individual decisions. If an association consists of the collective actions of its members, then how its members shape the nature of the association is critical. Beyond the stable influence of the mission statement, associations need dynamic mechanisms to recognize and support the professional commitments, research, programmatic redesign, curricular innovations, and individual struggles of their members as they seek to improve science education. These concerns vary over time and are embedded within and often in response to ever shifting contextual circumstances, disallowing their inclusion in mission statements. Current concerns with increased student diversity, curricular alignment with national and state standards, increased emphasis on high stakes testing, efforts to engage in systemic reform, and political threats to the science curriculum are different than the concerns that existed 10 or 20 years ago. Therefore, the challenge in the redesign of a professional organization is to find ways to be more responsive to the needs of its members within their ever-changing context while maintaining the continuity and commitments of the organization. AETS has accepted this challenge to find ways to have its members more actively shape its agenda and support its members in their attempts to redesign science education.

The Need for the Redesign of AETS

Organizations are organic creatures. They are created with clarity of vision and enthusiasm that helps establish their identity, members, and mission. But with time, the shape and form of the organizational structure morphs based on a plethora of small changes. Like textbooks, changes in organizations often occur through accretion. Recognized needs are often satisfied by the addition of a committee, award, publication, or procedure. While the individual change is carefully considered, the overall impact on the organization is often ignored. The cumulative effect is often an unwieldy organizational structure that is unresponsive to the needs of its members.

AETS is a case in point. According to its history written by Jacobson in 1977, AETS began in the late 1920s as a loosely organized forum for the exchange of ideas related to the status of science teacher education. With members being primarily located in the northeast, the group formalized itself as the Conference on the

Education of Teachers in Science in 1935. In 1953, the name was changed to its current form. While the history provided by Jacobson provides few details after 1974, certain elements can be reconstructed.

The initial national structure of AETS acted as an umbrella for several regional groups who met together annually to discuss issues related to the preparation of science teachers. Loosely dividing the US into seven regions, (Far West, Mid-Atlantic, North Central, Northeast, Northwest, Southeast, Southwest), the regional AETS units made up the infrastructure of the association as is reflected in the current structure of the board: 3 presidents, 6 elected board members at large, 7 regional directors, and 3 ex-officio members. Without a national presence of its own, gatherings of national AETS members occurred as an affiliate of NSTA. At the NSTA meetings, AETS conducted its annual business meeting, had 10 hours of program time dedicated to the organization at the national NSTA convention, and 2 hours of meeting time at each of the NSTA regional conferences. In the late 1980s, there were approximately 200 individuals who identified themselves as members of the national AETS and a large contingency who viewed themselves as primarily members of their regional association. Elements of these roots still exist today. AETS continues to be an affiliate of NSTA and maintains program time at the national and regional meetings.

The late 80s and early 90s brought many changes to the organization. A mission statement was drafted in 1993, guiding the efforts and direction of the association. In 1989, the *Journal of Science Teacher Education (JSTE)* was launched through Tufts University. This journal represented the second publishing venue offered through the association, the first being the Science Teacher Education section of *Science Education*. In 1996, Kluwer Academic Press was contracted to publish and distribute JSTE, increasing the international visibility of the association. In addition to these primary publications, AETS also sponsors sections in the *Journal of Elementary Science Education* and in *Contemporary Issues in Technology and Teacher Education (CITE Journal)*.

In 1992, the AETS board courageously voted to organize a national conference independent from NSTA. The first meeting was held in 1993 in Charleston, South Carolina in conjunction with the Southeast AETS Region and was attended by 277 members. This meeting both strengthened our national identity and acted as a

mechanism to attract new members. By 1999, national membership had grown to over 750, including 64 international members, and each annual meeting meets or surpasses the attendance at the previous meeting. The 2000 Annual Meeting in Akron, Ohio attracted 313 participants, 67 of who were new members.

Early in its development, AETS created three kinds of committees: elections, standing, and ad hoc. The Elections Committee, created in the early 90s, is completely outside the structure of the board and is elected by the membership to act as the nominating body for the association. Standing committees were originally viewed as central to the running of the organization and were to be chaired by board members to assure task completion. Examples of standing committees include Awards, Publications, Financial Advisory, and Program. Members of standing committees are appointed by the president-elect and typically serve a two or three-year staggered term. Board member chairs, however, often serve terms of only one year and then moved on to chair a new committee. The transitional nature of committee leadership has resulted in the loss of organizational memory, leading to the repetition of work. For instance, the International Committee has been dissolved and accidentally recreated several times due to a lack of communication about previous decisions. The result of this fragmented communication is the uneven implementation of committee work or the burdening of the bylaws and standard operating procedures with information that does not belong there.

Ad hoc committees were developed to take on short-term tasks and were established at the discretion of the executive committee or the president to achieve a specific goal. Examples of ad hoc committees include Middle-Level Science Education, Electronic Communications, Regional AETS Units, and Collaborations Among Science and Science Education Faculty. In 1999, there were 11 standing committees and 8 ad hoc committees.

This short overview of the association organization and history is important for two reasons. First, our organizational commitments are deeply rooted in the visions of both our current and founding members. These values and commitments make AETS unique from other professional associations and should be cherished and protected. Second, as a result of our evolution, the association faces new challenges. One consequence of our past is an organizational structure that functioned well when the national association acted as an umbrella for the regional units. Now, as a vital and

growing national organization, this structure needs to be reviewed and updated to meet our current needs.

The Focus of Redesign Efforts in AETS

During the 1999 summer board meeting, those in attendance considered the following question: How can we maintain the best elements of AETS, recognize our growth, better enact the values we hold, and be more responsive to our members? In my 10 years of participation in AETS board meetings, I know that these questions have often troubled the group. Three key issues were identified as critical for consideration: The composition and role of the board, the nature of committees, and the format and nature of the organizational governing documents. These issues are deeply intertwined, making their resolution more complex. For instance, a change in either the board composition or committee structure involves a change in the bylaws and standard operating procedures. Each issue and the potential alternatives proposed by the board will be addressed below.

Composition and Role of the Board

The current composition of the board is as follows: 3 Presidents (current president, president-elect, and past president – each with a staggered three year term), 6 Board Members at Large (elected by the membership with a staggered 3 year term), 7 Regional Directors (appointed or elected by their region with no standard term of office), and 3 Ex-Officio members (AETS executive secretary, NSTA president or designee, and NSTA Director of Teacher Education). The board identified several issues with this composition.

1) With the reorganization of NSTA, the Director of Teacher Education position was divided into two new positions – Director of Preservice Teacher Preparation and Director of Professional Development. With this change, how many NSTA representatives should serve on the board? In addressing this issue we discovered that the bylaws are silent on the voting rights of ex-officio members, resulting in inconsistent use of voting privileges over the years. What voting privileges should be allocated to ex-officio members?

2) Excluding consideration of the ex-officio members, there are 9 members of

the board that are elected by the membership at large and 7 that are elected or appointed by the regions. If the ex-officio members are granted a vote, 10 of the 19 voting members of the board were not elected by the membership as a whole. Is that composition still appropriate for an organization that has become much more national in scope and orientation? If regional directors are retained on the board, can or should their election or appointment procedures and terms of office be standardized? If they are to be removed from the board, how can their voice and important role be maintained?

3) Currently there are 9 board members with predictable terms of office and 11 standing committees. Therefore, if it is important that all board members chair a committee, and that all standing committees are chaired by a board member, there is a mismatch in number and responsibility. There are three solutions: assign standing committees to non-elected board members (regional directors) or members who do not hold board positions, decrease the number of standing committees, or increase the size of the board.

4) A quorum of the board is defined as a simple majority, or 10 members. In the absence of a quorum, the executive committee (the three presidents and the two senior board members at large) is granted the authority to make decisions on behalf of the board. Though it is not explicitly stated, in order to conduct AETS business, a majority of the executive committee must be present. There has rarely been a meeting in which there has been a full quorum of the board. This is often, though not exclusively, due to the lack of representation by NSTA and/or the regional directors. In some cases, inability to attend can be explained by the low levels of financial support that AETS can provide to cover travel expenses. In other cases, inactive regions have no formal mechanism by which to appoint a director. When a representative is sent from an inactive region, the question of whom they represent is of concern. Finally, based on the uneven terms of office and mechanisms of appointment of regional directors, the communication between the national board and the regions is poor and regional directors often do not know that they are expected to attend board meetings and/or the timing of their term of appointment as it relates to the national board.

Board Proposed Alternatives

After careful consideration, an alternative structure of the board was proposed to the membership at the 2000 Annual Meeting. In this proposal, the regional directors would be eliminated from the board and NSTA would have one representative. The final board composition would be the three presidents, six elected board members, and two ex-officio members (NSTA and the executive secretary). The bylaws would also be changed to state that ex-officio members do not hold a vote on the board. In addition, the board proposed that the regional directors become part of a standing committee, potentially prompting an increase in the number of elected board positions. The result would be greater decision-making power in the hands of nationally elected individuals and a smaller board, which would in turn increase the level of travel support for board members to attend the summer board meeting.

Nature of Committees

Many of the AETS standing committees have a limited number of member positions available for appointment each year as dictated by the bylaws and standard operating procedures. These numbers often prevent interested members from serving important and vital roles in within the organization and decrease the potential of recognizing and grooming new leadership potential from the membership at large. With the year-to-year nature of ad hoc committees, it is difficult to encourage committee momentum or identify members who are interested in serving on such committees. There are two perceptions that have resulted from this system: that one needs to be an "insider" to gain a committee appointment, and that standing committees are more important than ad hoc committees. One outcome of this perception has been a recent trend for ad hoc committees to petition the board to become standing committees. For instance, Informal Science Education and Inclusive Science Education have both changed from ad hoc to standing committee status in the last 5 years, increasing the number of standing committees beyond the size of the board. Several issues have arisen from this analysis:

1) How can the AETS committee structure be organized so that the work of the organization is conducted effectively and communicated efficiently back to the board?

2) How can continuity of membership, purpose, and leadership be provided to

more committees than can be sustained by board members? How can the committee structure within AETS more effectively reflect and be responsive to the commitments, concerns, interests, and agendas of its members?

3) How can increased opportunities for committee involvement and leadership be offered to the membership?

Board Proposed Alternatives: The board proposed a radical reorganization of the committee structure. The first step was to carefully analyze the nature and work of the standing committees to answer two questions: Which committees were essential to the running of the organization and thus required board leadership? Which committees had functions that could be combined? The result was to suggest 7 committees that would be renamed as Operating Committees. These committees were Program (with co-chairs), Long Range Planning, Financial Advisory, Publications (with co-chairs), Awards, Membership and Communications, and AETS Regions. This structure provides for 9 committee leadership positions to be filled by the board and added a new committee to represent the regions. Committee size, then, might need to be increased in order to provide for more member participation and the equitable distribution of the workload. The Elections committee would continue to be chaired by an elected non-board member.

The second step was to craft a new type of committee, tentatively called Forums. Forums would be member–originated groups designed to promote the professional development of its members through the sharing of ideas and the development of teaching, research, and/or program initiatives. Forums would establish their own leadership structure, recruitment mechanisms, and goals. AETS would provide forums with access to the board and its organizational structures – encouraging the development of publications, presentations, position statements, and collaborative research and program development opportunities. The board saw several advantages to this structure: Committees could arise and dissolve to meet the needs of the membership. Forums would allow for professional development and support in areas critical for our members and their professional contexts. Opportunities for committee involvement and leadership would increase and there would be no restrictions on forum size, allowing all members to participate. Potential forums were identified as Informal Science Education, Middle-level Science Education, Inclusive Science Education, and Science and Teaching in Higher Education. This organization was

seen as a reflection of the mission of AETS to be responsive to and supportive of its members as they worked to redesign science education.

Finally, the board proposed that ad hoc committees continue to exist to meet short terms needs identified by the board. In contrast to forums, which would arise from the membership, the board would create ad hoc committees.

The Format and Nature of the Organizational Governing Documents

The bylaws of AETS can only be changed with a majority vote of the membership. The standard operating procedures can be changed by a majority vote of the board. Both documents, in an attempt to create a home for important decisions, have become bloated in some areas and are silent in others. Inconsistencies exist in format and substance. The following issues have surfaced:

1) Which procedures and structures within the organization should remain stable and thus should only be changed by a vote of the membership, recognizing that this is a time consuming and expensive process? Which procedures and structures should have the flexibility to be changed by a vote of the board?

2) How can committee procedures and organizational decisions be best captured for future reference and to facilitate committee work?

Board Proposed Alternatives

It's pretty hard to get excited about organizational governing documents until they inhibit the work of the organization. The board thus recommended the rewriting of the bylaws and standard operating procedures so that they efficiently and effectively portrayed the work of the organization and so that the organizational decision-making and flexibility were located at the correct level. In addition, it was proposed that a set of Committee Operating Procedures (COPs) become part of the governing documents. The COPs would be originally designed by the committees, approved by the board, and maintained on the web for easy access by the membership. Changes to the COPs would occur through board action or based on committee requests. Such a document would provide for committee guidance and the preservation of organization memory.

Procedures to Facilitate Organizational Redesign

While the board recognized the importance and potential viability of the alternatives it proposed, we also recognized that, as board members, we understood the organization from an orientation unique from that of the membership. Our challenge was to create opportunities to educate the members about the issues that we had identified, propose alternatives, and provide the time and opportunity to consider the proposals or offer new ones. Our short-term goal was to expand our alternatives and gain buy-in from the membership on the proposed changes. Our ultimate goal was to present a rewritten set of governing documents to the membership for ratification that would include all the changes simultaneously.

The AETS board at the 2000 annual meeting hosted two open forums, or town meetings. An outline of the presentation was provided to the board members prior to the conference and several announcements and reminders about the town meetings were made prior to and during the conference. These meetings were well attended with over 60 members at each, and with several members electing to attend both. Using handouts describing current structures and proposed changes, the board presented the issues and alternatives, answered questions, and then turned the meeting time over to the membership to discuss what they had heard and offer comments, identify issues, and suggest alternatives. Comments and questions were recorded and organized by the board for consideration at the summer 2000 board meeting. As a board, we were pleased with the willingness of the membership to analyze the challenges that we outlined and to suggest other alternatives. In fact these meetings were so successful that they will now become a regular feature of the annual meeting, providing a direct channel of communication between the board and the membership.

In addition to the town meetings, several other discussions of the proposed changes occurred. Regional directors met as a group several times at the annual meeting to discuss the alternatives presented and suggest modifications. Members of the board met with interested and highly engaged members individually and collectively throughout the meeting. At the board meeting following the conference, reorganization issues were discussed again, as they were at the summer board meeting. To continue the conversation, I have dedicated the presidential newsletter column to further explain the issues and alternatives that are being considered. Based

on the prompting of the board, a column explaining the issues surrounding the reconstitution of the board without regional directors will be written and available for discussion at the regional conferences, which are typically held in October. It is important to the board that our members are well informed and supportive of the proposed changes before we move forward.

Lessons Learned: Guiding Principles for Organizational Redesign

In the process of participating in this venture to redesign AETS, we have learned a number of lessons about the redesign process. Some lessons have been learned as members of the board, struggling to articulate and implement the vision of our organization. Many of the lessons have come from listening carefully to our members. All of the lessons have the potential to inform other redesign efforts.

Change takes vision

The AETS mission statement has been a powerful force in helping us identify and enhance the unique contribution that AETS makes within the science education community. Our members helped provide the form to this vision by giving us feedback: They want an organization that is responsive to their needs and provides professional support for their efforts to redesign science education. To achieve these goals, our members want an association that provides formal and informal opportunities to share their successes and challenges; offers support for these efforts in a friendly, collaborative atmosphere; and creates opportunities to share in the leadership and direction of the organization. As a board, we are indebted to the work of our members who helped shape the original mission statement and the continuing efforts of our members to articulate the vision for the association.

Change takes education

Through feedback, we have learned how personally engaged each AETS member is with the organization. With that engagement comes differing perceptions about how the organization does and should work. For instance, many of our members are only associated with AETS through the national organization. As members of other national organizations, easy parallels are drawn in expectations,

perceived operating procedures, and mission between AETS and these other associations. Therefore, clarifying how AETS is similar to other professional associations and how we are unique is an important education issue. This message has been reinforced by member-requests that we not take on the characteristics of other associations. Other members are strongly committed to and involved in their regional units. Based on our organizational history, the buy-in of these members to the national association is essential to our health and mission. On occasion, however, the needs and operations of the regional associations become confounded with that of the national. Educating members about how these association levels can operate synergistically has been an important challenge in the redesign process. Finally, we recognize that the board has a different relationship with the association than does its members. A board is responsible for the operation of the organization and, with that responsibility, must be concerned with issues of consistency, communication, efficiency, and the provision of high quality products such as annual meetings and publications. Members are the recipients of these efforts and evaluate the quality of the decisions that are made and the products that are produced. For instance, organizational structures are less important than the responsiveness of the association to meeting their professional needs. Educating both groups to the perceptions of the other is essential to the acceptance of change.

Change is threatening

It is easy to grow comfortable with what we know, and change threatens the perceptions of stability that we hold. We have learned to listen carefully to the anxiety that change has promoted in some members and have worked hard to analyze the cause of their concern. For instance, two issues elicited strong reactions: the reassignment of the role of the regional directors and the designation of some current standing committees to forums. Why such concern? "Change" is a simple yet insufficient answer. In a careful analysis of our member's comments, a more important answer was found. AETS members value the informal and accessible leadership structure of the association. Both our size and our mission allow leadership opportunities for individuals that seldom exist in other organizations. As a result, AETS is viewed as a mechanism for individuals to build leadership skills and impact the national or regional science education agenda. Therefore, some changes were seen

as a threat to accessibility. Small changes in the annual meeting also increased the levels of anxiety felt by many. The 2000 annual meeting venue necessitated a decrease in presentation times and discouraged spontaneous informal conversations between sessions. Though not by design, these two changes highlighted the values of our members, elements that will be purposefully attended to in future meetings. As a result, the juxtaposing of organizational and meeting changes may have heightened the sensitivity of our members to change as they sensed a shift to imitate other associations. As a board, this analysis helped us more clearly identify those values that AETS members cherish, and helped us to more specifically address the potential outcomes of the proposed changes.

Change takes time

While individuals can often make changes with amazing speed, groups move much more slowly. This is especially true when buy-in for change is considered essential, as is true for the changes proposed for AETS. The board has discussed some of these issues for at least five years, with concentrated conversations occurring in the last three years. Discussions with the membership have occurred for over a year and I anticipate that they will continue for another year before we are sufficiently convinced that the changes proposed will result in a stronger association and will be accepted by the membership. The time needed for such changes presents a special challenge for leadership, who often rotate out of office before the change efforts are complete.

Change takes courage and commitment

Change takes organizational courage. As a group, we must be willing to tolerate the short-term discomfort with change in order to achieve the long-term benefit to the organization. Change takes personal courage. In a leadership role, it takes courage to publicly propose changes that are often temporarily unpopular and to accept the criticism that it engenders. In a membership role, courage is needed to consider proposals, offer alternatives, and to voice resistance when needed. Through this process, we have learned about ourselves, the organization, and the commitments of our members. Most importantly, change takes the courage and commitment to venture organizationally into uncharted territory with the hope, but not guarantee, of success.

The leadership of AETS is committed to continuing the conversations about the redesign of our organization. Such conversations are essential to our organizational health and demonstrate our commitment to the profession and each other as we pursue the redesign of science education. Through AETS, we hope to have a collective impact on the shape of science education through our individual efforts. In order to achieve this mission, AETS hopes to support the professional development and achievements of our members. Through the redesign of AETS, we hope to more effectively support the professional development of our members by being more responsive to their needs.

Notes and References

The AETS Mission Statement can be found at www.aets.unr.edu.

The NARST Mission Statement can be found at www.narst.org.

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Redesign: The Changing Role of Professional Societies

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The American Institute of Physics (AIP) is an umbrella organization serving ten professional physics and physics-related societies[1]. The Institute's core purpose is the advancement and diffusion of knowledge of the science of physics and its applications to human welfare. Furthermore, the Institute seeks to promote unity and effectiveness of effort among those devoted to physics by research, by application of its principles, by teaching or by study; and to foster the relationship among of the science of physics, other sciences and the arts and industries.

Although separate organizations; the eleven societies work cooperatively on core functions. The most important of these functions is education. This paper will cite examples of how AIP and some member societies are working together on key education programs.

Increasingly, AIP and its Member Societies are assuming a leadership role by encouraging their members to actively engage in the education of all students. For example, AIP and several of its Member Societies recently released a statement on the role of physics and faculty members in related fields in educating the next generation of K-12 teachers[2]. In part, it states that: "*The scientific societies listed below urge the physics community, specifically physical science and engineering departments and their faculty members, to take an active role in improving the pre-service training of K-12 physics/science teachers... Strengthening the science education of future*

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[1] The AIP member societies are: The American Physical Society, Optical Society of America, Acoustical Society of America, The Society of Rheology, American Association of Physics Teachers, American Crystallographic Association, American Astronomical Society, American Association of Physicists in Medicine, American Vacuum Society, and American Geophysical Union.

[2] For the complete Statement, see http://www.aip.org/education/futeach.htm

teachers addresses the pressing national need for improving K-12 physics education and recognizes that these teachers play a critical education role as the first and often-time last physics teacher for most students". The statement addresses the education of the many students who take introductory courses, often designed for the disciplinary major, who go on to become K-12 teachers. It questions whether those students receive the pedagogy and content they need to become effective teachers.

The American Physical Society (APS), a Member Society, recently released a statement that reaffirmed the importance of the emerging subspecialty, Physics Education Research. In part, it reads;[3] "*Physics education research can and should be subject to the same criteria for evaluation (papers published, grants, etc.) as research in other fields of physics... The successful adaptation of physics education research to improve the state of teaching in any physics department requires close contact between the physics education researchers and the more traditional researchers who are also teachers. The APS recognizes that the success and usefulness of physics education research is greatly enhanced by its presence in the physics department.*" It should be noted that the number of Physics departments with active Research in Physics Education Groups continues to grow.[4] AIP and its Member Societies are actively engaged in efforts to encourage the integration of education research into the daily classroom activities of other practicing physicists.

The American Association of Physics Teachers (AAPT), in coordination with the American Institute of Physics and The American Physical Society, recently established the National Task Force on Undergraduate Physics to address departmental responses to changes in the environment for undergraduate physics at colleges and universities. Efforts will focus on finding and analyzing models of department changes that work; developing case studies; and providing advice to professional organizations, funding agencies, and the physics community at large about the full range of activities and careers in physics.[5] The goals of the Task Force

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[3] For the complete Statement, see http://www.aps.org/statements/99.2.html "

[4] For a listing of Research in Physics Education Groups, see http://www-hpcc.astro.washington.edu/scied/physics/physresearch.html

[5] For complete information on the purpose and goals of the task force, see http://www.aapt.org/programs/ntfup/index.html

are to:

- To provide an overview of undergraduate physics revitalization efforts and to coordinate the efforts of physics professional organizations, individual physicists and physics departments, and funding agencies.
- To identify areas in which revitalization efforts are needed and to catalyze projects addressing those needs.
- To raise the visibility of undergraduate physics revitalization by having its members speak and write about the revitalization effort and maintain communications with the entire physics community.
- To develop contacts with undergraduate revitalization efforts in the other scientific disciplines and to promote physics as a model for undergraduate revitalization efforts.

The Task Force believes that on the undergraduate level, physics departments have contact with students who will go on to become tomorrow's leaders in science, education, and other fields. In many ways, undergraduate physics sets the tone for physics education in that tomorrow's K-12 teachers are today's college and university students.

The APS, AAPT and AIP also recently launched the Physics Education Teacher Coalition (PhysTEC).[6] This nation-wide project will enhance the role of undergraduate physics departments, in collaboration with education departments, in creating more and better-prepared science teachers. The project emphasizes, in part:

- A long-term, active collaboration between the physics department, the school or department of education, the local two-year colleges, and the local school community
- The redesign of targeted physics courses by physics faculty
- The integration of learning theory, teaching methods, and physics content

The AAPT has also established the Physical Sciences Resources Center (PSRC).[7] This web-based center provides resources for physical science and physics teachers on all levels, K-16. The PSRC has curriculum materials and links to other

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[6] For more information, see http://www.aps.org/educ/program.html. For other APS outreach programs, see http://www.aps.org/educ/program.html.

[7] See http://www.psrc-online.org/

curriculum materials, including software and multimedia resources for classroom use. Whenever possible, the website also provides links to post-use reviews of these materials.

Powerful Ideas in Physical Science aspires to play an important role in improving the relationship between student and teacher and in guiding how instructors view the entire learning process. This 1000 page, undergraduate course model allows college and university faculty to build an introductory physical science course for preservice elementary teachers. It uses flexible materials to guide the student's personal conceptual development. The student materials are available in both hard copy and electronic format to facilitate adoption to any given teaching situation. This course was developed by the American Institute of Physics and the American Association of Physics Teachers under a grant from the National Science Foundation, DUE-9496330.[8]

The goals of this course are to provide:

- A new and innovative teaching tool for college and university faculty who instruct prospective elementary teachers and non-science majors in elementary physical science phenomena concepts.
- A set of innovative instructional approaches making use of more than a decade of research in physics learning. The materials are suitable for use in large or small class settings.
- A flexible manual that includes assessment strategies that assists in developing techniques that assess meaningful learning.
- A model course with extensive, annotated Instructor Materials. Student Materials are available in hard copy and electronic format to facilitate adoption to your particular situation.

Working with Other Organizations

AIP and its Member Societies often collaborate with other Societies headquartered in the Washington, DC area to promote their respective education

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[8] For more information, see http://www.aapt.org/programs/pipsprod.html

agendas. An example of the increasing emphasis on K-12 education by professional societies is the recently released Intersociety Statement on K-12 Science, Mathematics, Engineering, and Technology Education.[9] It states in part; "*The science, mathematics, engineering, and technology communities strongly urge federal policymakers to make improved student learning in elementary and secondary science, mathematics, and technology education a national priority... Increase educational research to determine effective science, mathematics, and technology education teaching strategies and how students learn.*"

The National Research Council recently published a monograph that addresses pre-college preparation for students in science, mathematics, engineering and technology (SME&T). The joint roles and responsibilities of faculty and administrators in arts and sciences and in schools of education to better prepare teachers of K-12 mathematics, science, and technology was emphasized. The monograph suggests how colleges can improve and evaluate lower-division undergraduate courses for all students, strengthen institutional infrastructures to encourage quality teaching, and better prepare graduate students who will become SME&T faculty.[10]

AIP and its Member Societies hope that through their joint efforts, educational institutions at all levels will see the value of quality education for all students. Furthermore, the hope is that discipline specific faculty will began to work with faculty from schools of education to ensure that all students get a quality education in math and science. Hopefully, college and university faculty will increasingly work with K-12 faculty to better assess and address the needs and requirements for the redesign of the K-16 curriculum.

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[9] For the complete statement and the list of the sponsoring organizations, see http://www.aps.org/educ/coe/statement.html

[10] For more information, see http://books.nap.edu/catalog/blurb_catalog.phtml?val1=6453&val2=toc. For other resources from the National Academy of Science, see http://www4.nationalacademies.org/cfe/cfe.nsf/web/cfe_publications?OpenDocument.

Session V.

Defining Redesign

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The BioQUEST Curriculum Consortium

John Jungck
Beloit College

(See addendum)

System Reform at the State Level

Steven P. Meiring
Project SUSTAIN, The Ohio State University

Context

Ohio was one of the first ten states to receive funding under the State Systemic Initiative of the National Science Foundation. From 1991 to 1995, Project *Discovery,* a collaborative state effort guided by the Ohio Board of Regents and the Ohio Department of Education, received $2M per year from NSF and $2M in matching funds from the Ohio General Assembly for statewide systemic improvement of K-12 mathematics and science education. The main thrust of this effort was upon sustained professional development institutes (six weeks) for middle school teachers through research-based, inquiry teaching models such as *Physics by Inquiry.*

From 1995 to the present, OSI-*Discovery* has continued the systemic improvement mission with $2-3M annual funding from the state of Ohio. The scope of its activities have enlarged to include: (1) teachers, schools, and districts grades K-12; and (2) teacher education through a higher education component, Project *SUSTAIN.* By 1999, approximately 5000 teachers had participated in *Discovery* institutes, taught by scientists, mathematicians, teacher educators, and master teachers. Another 5,400 teachers had participated in regional or local institutes taught by *Discovery*-trained leaders. Thirteen state-assisted university programs have received three rounds of funding to assist their teacher education programs to institutionalize inquiry-based teacher education. Currently, these programs are expanding to form collaborative partnerships with two-year and private institutions in the preparation of teachers of science and mathematics.

The Ohio systemic initiative has been demonstrably successful in these specifics:

- Effecting a deep cultural reshaping of teacher participant beliefs and practices

- Raising achievement scores of students, particularly in buildings with a critical mass (51-100%) of *Discovery* teachers
- Narrowing the performance gap of minority students with their majority peers
- Training the next cadre of teacher leaders, much like the 1960s teacher institutes
- Instilling inquiry-based programs like FAST, DASH, CGI, CMP, and Core-Plus
- Facilitating inquiry-based teacher education programs at state-assisted universities
- Promoting collaboration on teacher education among Arts & Science and Education faculty
- Initiating collaborative teacher education projects among state-assisted universities, two-year colleges, and private institutions

The Ohio systemic initiative has yet to accomplish these significant system needs:

- Finding the resources and capabilities to scale-up sufficiently to impact at least 50% of target teachers K-12
- Solving the infrastructure and school improvement support needs of K-12 teachers and administrators,, particularly as they relate to **program** improvement rather than **individual** growth
- Providing adequate professional development and program support mechanisms for higher education faculty, particularly in Arts & Science and in two-year and private institutions
- Becoming an integral part of state agency planning and implementation, particularly with respect to the Ohio Department of Education

Session VI.

Next Steps

Science Pivots around Middle

Mary Lightbody
Gifted Intervention Specialist, Hilliard City School, Hilliard, OH

Science teachers in the middle school classroom might teach 6th, 7th, 8th, or sometimes 9th grade students. Our certification might be elementary, grades 1 – 8, or secondary, grades 7 – 12. A teacher with secondary science certification has a major or minor in science content, whereas the elementary certified science teacher may have only taken two or three college science courses. To be fair, many elementary certified middle school science teachers have taken far more than this minimum. Teachers with either certification are expected to teach certain concepts and principles to the middle school students who come to our classes every day. This curriculum has been determined by the district, and is designed to correlate with state and national standards for each grade level. However the district course-of-study may change from time to time as different measures are introduced to improve student performance or to align the curriculum with evolving standards. Every middle school science teacher can therefore expect to teach each branch of science at some time during his or her teaching career. However the expectations do not stop at the classroom door.

Middle school teachers, whether we teach math or science or some other subject, have to deal every day with the mercurial middle school student. The typical student enters 6th grade as a diminutive and cooperative teacher pleaser, and exits two or three years later as a gangly rebellious socially conscious teenager. The transition takes place, it often seems, right in the classroom. Science classrooms are apt to be noisy rooms, if teachers attempt to engage students in hands-on cooperative lab experiences, for the middle school student dearly loves to talk. The science teacher must focus on providing experiences that enable students to learn the curriculum designated by the district for that year, and in most states must prepare students for a state proficiency test and other standardized tests. To help student achieve success, the middle school science teacher's efforts can not stop at the door of the school building either.

Every middle school teacher seeks to develop strong contacts and partnerships

with parents, and to involve community members in classroom experiences whenever possible. The best middle school science teachers make science real. We help students identify local problems, and seek solutions through scientific investigations. We start gardens with our students at the school, identify trees growing in the community, and help plant more varieties. We organize recycling drives and hazardous-waste disposal events. We engage students in lessons that allow for real-world experiences and for opportunities for students to broaden our horizons and career interests. We bring guest speakers to the classroom, and send students out into the community. The best science teachers plan integrated units with other teachers on their instructional teams. They create opportunities for students to engage in lessons in one class which closely relate to lessons in another class. These connections help students learn the most challenging concepts in the curriculum, and retain the understandings they develop. The best middle school science teachers also constantly seek to provide extensions and choices for students who excel and tutoring for those who lag, even at the expense of time before or after school.

Middle school is a turning point for many students, who want distance from their own parents but still need nurturing adult role models. Enter the best middle school teachers, who organize, attend, and support school activities and events, fundraisers, and other community activities. Look for middle school teachers who accept supplemental contracts to coach athletic or extracurricular activities, either at the middle schools in which we teach, or at the high schools to which our students matriculate. Look for middle school teachers to be very involved with the students in our classrooms, yet look for us to be reflecting on our own teaching, and seeking ways to improve our performance in the classroom as well.

The middle school science teacher has particular challenges that many other teachers do not have. One year we might teach semester courses in chemistry and physics, only to have the principal ask the next year that we teach the earth, space, and/or life science curriculum instead. Another year an integrated curriculum may be adopted, and science teachers must find ways to teach big concepts, such as "change," through all the sciences. The middle school science teacher also must stay current with the changes and growth in the collective body of science knowledge and understandings. At no other time in history has the body of science knowledge been expanding as rapidly as now, with improved technologies and the vast calculating

power of computers. A good middle school science teacher might read newspapers and science related magazines, visit bookmarked science web sites or subscribe to listserves for science teachers, listen to NPR Science Friday and other radio programs, watch PBS television programs, and/or try to find the New York Times every Tuesday to read the Science section. The best teachers ask students to do the same, and have regular class discussions of science in the news. Science teachers always have more to learn.

Science teachers must pay close attention to our own professional development as well. We join professional organizations such as NSTA or SECO to stay current and to develop contacts with other science teachers. Whenever possible we attend the conferences these organizations sponsor to attend concurrent sessions on topics of interest, learn from other science teachers and scientists, and roam the exhibition halls looking for new resources and ideas. We take classes at local colleges and universities to learn how to use new teaching strategies or new technology effectively in our classrooms. We are often the first in our schools to achieve technology proficiency and certification through local professional development organizations. The middle school science teacher is quick to recognize that providing opportunities for students to collect data using calculator- or computer-based probes allows them to move beyond tedious data collection and graphing to a deeper analysis and synthesis of their results.

We even write grants to secure funding for the equipment we need as we mostly teach in underfunded schools with tiny budgets for science departments to share. We also attend inservice courses/workshops to learn how to implement inquiry activities and lessons, and how to create standards-based lessons for our students. We participate in action research projects with colleagues, and look for meaningful summer experiences such as curriculum writing or special workshops. Even as we reflect on these experiences, and prepare to return to the classroom each fall, we increasingly realize that we will see new faces holding lesson plans and grade books in classrooms adjoining our own, and that these new teachers need help too.

With high rates of retirement by our experienced colleagues, new science teachers join us every year. As experienced science teachers, we are expected to engage in active peer mentoring of the new science teachers as they join our middle school communities. In Ohio changes in licensure policies require many experienced

teachers and all new teachers to plan and implement their own professional development curriculum in order to retain licensure to teach. The Individual Professional Development Plans (IPDPs) require teachers to submit a plan for approval, and to enroll in planned course work and workshops to achieve self-identified goals. Pre-service educators just joining the teaching ranks will need mentors to achieve licensure; these mentors will perforce be the experienced middle school science teachers who remain after the wave of retirements expected in the next five years. To be a successful classroom teacher does not mean one is necessarily a successful mentor, so add to the list of responsibilities middle school science teachers already carry the need to learn how to engage in peer mentoring and to supervise student teachers and interns.

For some experienced science teachers the best path to helping new science teachers reflect on their teaching is to embark on National Board Certification. There are currently two national certifications for science teachers, one in Early Adolescence Science, and another in Adolescence and Young Adult Science. Both require candidates to submit six portfolio entries and to take an examination on science content, assessing student work, and the process of teaching science. With a forty-five percent (45%) passage rate, this is not the path for the weak spirited or faint of heart. Yet the experience is unrivaled for depth of learning and growth as a teacher. I can highly recommend it, whether I am successful this year or not. The process provided an opportunity for self-analysis and self-reflection that I have never been able to accomplish before, although I have many of the characteristics of the ideal middle school science teacher, have been an active and reflective science teacher, and have produced two professional portfolios previously.

In all honesty to paint such a picture of the consummate science teacher is to be generous and idealistic. Time is a great challenge, for we can not achieve the ideal every day and every year. We can but set goals, and make improvements each year. With luck and hard work, our students benefit from our efforts and learn enough science from us to be successful in the high school years that follow. With coordination, careful planning, and shared resources, our colleagues within the science department complement and supplement our weaker areas, and together we provide our students with better planned lessons than had we tried to work alone behind a closed door. Hard work and honesty are required in any reform effort, and a

willingness to recognize the need to change. For many teachers this last requirement is perhaps the most difficult to accept. Personal experience has taught me that change is a constant in our lives, and can be a catalyst for significant and positive professional growth.

For five years, from the fall of 1995 until the spring of 2000, I was a member of the Teacher Support Team (TST) with the Columbus Urban Systemic Initiative (USI). My responsibility as a middle school science teacher on special assignment was to support other middle school science teachers in the district, and to work together with them to improve student performance on proficiency test outcomes. The Teacher Support Team attempted to provide professional development for science and mathematics teachers in grades K to 12 the way research has shown it to be effective: during the school day, with teachers and their students, in their classrooms, and over considerable time. I am convinced that I personally learned more than anyone involved in the grant, and would recommend the experience to anyone.

To be honest, not every middle school science teacher fits the rosy picture I have presented here. Not every teacher with whom I worked during the five years of the grant was receptive to my attempts to help them, and not every day brought success. Most of the teachers with whom I worked during those five (5) years were stressed by the realities of their teaching assignments. Yet many of them were willing to try to implement some changes because I was there to help them, and because they felt comfortable taking risks under those circumstances. A few were not willing to accept help with any aspect of their teaching, and I felt that my very presence in the building only added to their stress levels. I tried to be a support and not a threat of any type, but the USI did ask the district and its science and mathematics teachers to examine our instructional practices, and look for ways to improve. For a few this request seemed to require too great a personal risk or too large an effort on top of an already overwhelming work load. The first year especially seemed fraught with difficulties, and even our own education association questioned our efforts and motives. With time and continuous effort, we were able to move past the worst roadblocks, and did achieve some degree of success with the USI program in the Columbus Schools.

Over the duration of the grant the majority of the science teachers in the fourteen buildings in which I worked welcomed me eagerly. They were gracious and open, had numerous questions, and would try anything if they thought the new lesson or strategy

would help their students learn. These teachers were easy to help. Many of these teachers continued consciously to work to improve their teaching even after I moved on to other middle schools, and still provide meaningful and exciting lessons for their science students. I freely admit that I myself learned from the teachers with whom I worked, and found that simply sharing ideas I found in one building with teachers in another allowed all the teachers to be more successful. Together we can achieve more.

We reached the end of the five year term of the National Science Foundation (NSF) grant in June, 2000. The forty (40) members of the Teacher Support Team responded to a series of questions in exit interviews[1] conducted by our USI supervisors in May. The Executive Summary contains sentence fragments of much longer statements, but clearly provides the careful reader with some directions for future efforts.

It is clear to me that the professional development in which we participated helped each one of us become better teachers. Learning to work with our peers helped us be more effective in the classroom. The forty of us have scattered through the district; a few of us left for opportunities elsewhere. We each continue to share our message with any audience willing to listen.

Teachers can be our own best sources of information, strategies, and problem solving techniques. We can help each other with the work we have stretched out before us. Start with some small first steps in your own school or district. Find a colleague who wants to become a better teacher, and would be willing to help you achieve that as well. Develop an open, honest, and trusting professional relationship with this colleague. Become friends. Spend time together talking about what objectives you plan to teach, how you will know when or if your students have learned the objectives, how you might present or structure the lesson or unit, and how to find the materials, equipment, or resources you will need to provide your students. Ask your colleague to come into your class to observe and help, and be prepared to do the same for your colleague. Talk about the lesson after your students have left, and talk about what you would change if you were to do the lesson again. Ask your colleague for suggestions and comments, and listen to what he or she says. Look at the products students create, and find authentic audiences for their work. Takes notes

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[1] The Executive Summary of these interviews is included as Appendix I of this paper.

and write down your ideas. Share your efforts with other teachers, and encourage them to work with you. Set goals for yourself each year, and work to achieve them. Your students will thank you for your efforts long after they leave your classrooms.

Our eighth graders move on to a series of high school science courses that depend upon the foundation established in middle school science courses. Some of these students find a love of science in our middle school courses that provides them with sufficient self-confidence and interest in science to continue to take more than the required science courses in high school, and to continue in college. These are the scientists of the future who will make new discoveries, who will manage our green Earth, and who will preserve it for us all. Take full credit for their interest and love for science, and be glad you were a middle school science teacher after all.

Suggested Resources

National Research Council. *National Science Education Standards*. National Academy Press, 1996.

Rakow, S. J. editor. *NSTA Pathways To the Science Standards,Guidelines for Moving the Vision into Practice, Middle School Edition*. NSTA, 1998.

Appendix I

Executive Summary[2]

USI Exit Interviews Responses, May 16, 2000

Question 1:

WHAT IS THE MOST IMPORTANT THING YOU HAVE LEARNED ABOUT HOW STUDENTS LEARN MATH AND SCIENCE, AND HOW TEACHERS TEACH MATH AND SCIENCE?

- Students learn by doing, using manipulatives, to see how things work.
- There are many different learning styles.
- Too many teachers still rely on lecture and worksheets.
- There is not enough content knowledge among many elementary certified teachers.

Question 2:

WHAT FACTOR DO YOU THINK HAS THE SINGLE GREATEST POSITIVE IMPACT ON STUDENT ACHIEVEMENT IN MATH AND SCIENCE?

- For teachers - content knowledge, enthusiasm, belief in student ability
- Classroom environment - safe, nurturing, positive
- Technology
- Assessment

Question 3:

NAME THE MAJOR CHARACTERISTICS YOU THINK EFFECTIVE SCHOOLS ARE MOST LIKELY TO SHARE.

- Leadership and team spirit
- Parent and community support
- Value and respect for participants
- Common goals and expectations
- Open communication

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[2] Edited by Ellen Chaney, Madelaine Gentry, and Teddy Pahl, Columbus Urban Systemic Initiative, Columbus Public Schools.

Question 4:

WHAT PROFESSIONAL DEVELOPMENT TRAINING THAT YOU RECEIVED IN THIS JOB POSITION MOST HELPED IN THIS POSITION?

- Training for USI Plus and the CECA model (Dr. Jeff Smith)
- Building relationships
- TST partner
- The change process
- Benchmark and curriculum writing
- Attendance at professional conferences

Question 5:

IF YOU COULD REQUIRE ONE PROFESSIONAL DEVELOPMENT OFFERING TO IMPROVE MATH AND SCIENCE TEACHING IN THE DISTRICT, WHAT WOULD IT BE?

- Benchmark training
- Technology training for classroom use
- Teaching a course to other teachers
- Attending professional conferences
- Investigating a variety of learning styles

Question 6:

WHAT DO YOU SEE AS THE SINGLE BIGGEST OBSTACLE IN IMPLEMENTING A STANDARDS BASED CURRICULUM DISTRICTWIDE? WHAT SUGGESTIONS DO YOU HAVE TO OVERCOME THESE?

OBSTACLES:

- Lack of training with optional inservice attendance
- Lack of time
- No accountability for classroom instruction

SUGGESTIONS:

- Make inservice attendance mandatory
- Provide release time
- Give teachers support
- Encourage ownership

Question 7:

IN 4 OR 5 SENTENCES, ATTEMPT TO SUM UP YOUR YEARS WITH THE USI PROJECT.

- Changed own attitude
- Met many great professionals
- Furthered personal professional development
- Utilized new resources
- Gathered teacher support
- Learned that teacher motivation is the key
- Saw the big picture: district politics, K-12 curriculum
- Realized that GROWTH=CHANGE
- Determined that math & science facilitators are needed in the buildings.